

GENERAL ELECTRIC
REVIEW
Illinois U Library

TABLE OF
CONTENTS
Page Three



June, 1948

To **Reduce** carbon brush inventory with "National" brushes!

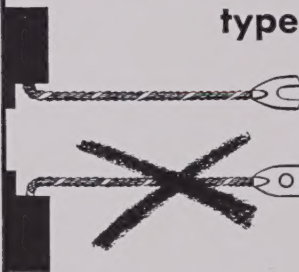
The lack of standardized specifications has always been the bugaboo of carbon brush applications. Here are ways to simplify these specifications and reduce your inventory.

1. Use only two shunt lengths.



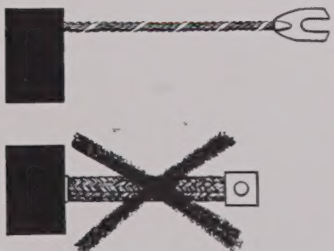
Why specify so many different shunt lengths for identical brushes used on different types of motors and generators? Experience shows that only two shunt lengths— $3\frac{1}{2}$ and $5\frac{1}{2}$ inches—are necessary.

2. Substitute slot- for hole-type terminals.



Slot-type terminals are easier to attach to terminal screw. Standardize on the slot-type and you further reduce brush inventories.

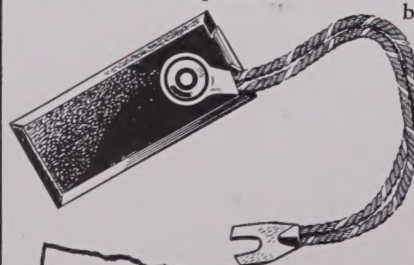
3. Use stranded instead of braided cable.



Stranded cable is suitable for any type connection. Braided cable is not suitable for Q-type connections. By standardizing on stranded cable, you gain further inventory reduction.

HOW BRUSH STANDARDIZATION PAYS_

1. Permits buying in economical quantities
2. Fewer small orders—with savings in bookkeeping, billing, and accounting
3. Less money and space tied up in brush stocks
4. Less time needed to handle stock



The term "National" is a registered trade-mark of
NATIONAL CARBON COMPANY, INC.
 Unit of Union Carbide and Carbon Corporation



30 East 42nd Street, New York 17, N. Y.
 Division Sales Offices: Atlanta, Chicago, Dallas,
 Kansas City, New York, Pittsburgh, San Francisco

Why carry hundreds of special carbon brush sizes and types when a **few standard** brushes will do the job as well?

GENERAL ELECTRIC

Review

JUNE, 1948
Vol. 51, No. 6



MAGNETIC SUSPENSION

One of the highlights of the revolutionary watt-hour meter described on page 11 is the successful application of the magnetic-suspension principle to replace the jeweled-bearing support, thus eliminating a major cause for maintenance. Shown on the COVER is the rotating element of the new meter, suspended in space by the magnetic field of two small cunico magnets. One of these, shown here supported by hand, surrounds an inner one attached to the upper end of the disk shaft.

ADVERTISING INDEX

Aluminum Company of America.....	5, 59
American Brass Co.....	2
Anaconda Copper Mining Co.....	2
Armco Steel Corp.....	9
Brand & Co., Wm.....	6
British Thomson-Houston Co. Ltd.....	23
Brush Development Co.....	17
Canadian General Electric Co. Ltd.....	40
Clare and Co., C. P.....	64
Clarostat Manufacturing Co., Inc.....	40
Cornell-Dubilier Electric Corp.....	8
Distillation Products Inc.....	49
Driver-Harris Co.....	62
Edison-Swan Electric Co. Ltd.....	23
Ferguson, Pailin Ltd.....	23
General Electric Co.....	31, 32, 34, 3d cover
Giannini, G. M., & Co. Inc.....	56
G-M Laboratories, Inc.....	63
Harcourts Ltd.....	23
Hotpoint Electric Appliance Co. Ltd.....	23
Ilsco Copper Tube & Products, Inc.....	30
Ingersoll-Rand Co.....	1
Instrument Specialties Co. Inc.....	61
Mallory, P. R., & Co. Inc.....	57
Metropolitan-Vickers Electrical Co. Ltd.....	23
Metropolitan-Vickers-GRS Ltd.....	23
Meyercord Co.....	53
Murray Hill Books, Inc.....	60
National Carbon Co.....	2d cover
New Departure—Div. General Motors Corp.....	4
O. Z. Electrical Manufacturing Co.....	7
Roll-A-Reel Co.....	61
Sexton Can Co., Inc.....	40
Sherron Electronics Corp.....	48
SKF Industries, Inc.....	16
Sola Electric Co.....	4th cover
Sprague Electric Co.....	24
Ward Leonard Electric Co.....	23
West Virginia Pulp & Paper Co.....	30
Wiley, John, & Sons, Inc.....	58

J. S. SMITH
Manager

E. C. SANDERS
Executive Editor

J. E. GLICK
Associate Editor

EDITORIAL CONTENTS

FRONTISPIECE: Electric Giant 10

ARTICLES:

Revolutionary Advances in Watthour Meter Design I. F. Kinnard 11

A completely new meter design, embracing an ingenious suspension method, new materials, and new techniques

Electric Equipment for 5000-hp Great Northern Locomotives: Part I H. S. Ogden and L. H. Burnham 18

The various components, their association, and their operation

Radio-frequency Resistance Meter H. W. Kline 25

Utilizes unusual circuit to measure effective resistance and other parameters more directly and with greater accuracy

Trends in Air Conditioning and Refrigeration: Part I W. E. Johnson 35

A subject of concern not only to the engineers and architects directly involved but also to the electric utilities

New Tester for Ball-bearing Greases Marshall Anderson and Dr. D. F. Wilcock 41

This small functional unit designed for widespread use

Are New Types of Transformer Oil Needed? Part II F. M. Clark 43

Operating tests and interfacial tests. Inhibited oils and the problems they introduce into commercial operation

Secondary Emission: Part II Dr. L. R. Koller 50

Devices in which secondary-emission phenomenon is utilized

DEPARTMENTS: Trade Literature 60

High Lights and Side Lights . 54 Book Reviews 60

New Products 56 Library Notes 63



INDEXED BY INDUSTRIAL ARTS INDEX, ENGINEERING INDEX, SCIENCE ABSTRACTS

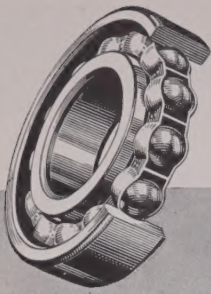
Editorial Advisory Board: H. A. WINNE, Chairman • H. L. ANDREWS
Dr. W. R. G. BAKER • H. V. ERBEN • Dr. WARD HARRISON

CIRCULATION DEPARTMENT: General Electric Review, Schenectady 5, New York,
SUBSCRIPTION RATES: Payable in advance. United States and Possessions and countries
in Pan-American Union, one year \$3.50, two years \$5.50. Canada, one year \$3.75, two years
\$5.75. Other foreign countries, \$4.00 a year, \$6.00 two years. Public and college libraries,
professors, and enrolled students deduct \$1.00 from annual rates. SINGLE COPY 35¢

CHANGE OF ADDRESS: Give old and new addresses. Notices received before the fifteenth
of the month will be effective with the next issue.

ADVERTISING DEPARTMENT: General Electric Review, Schenectady 5, New York.

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y.,
under Act of March 3, 1879. Published monthly by General Electric Company, 1 River Road,
Schenectady 5, N. Y. Printed in U. S. A. Copyright 1948 by General Electric Company.



Help in Bearing Application

From The Industry's Most Complete Library



● Back of the successful performance record of New Departure Ball Bearings, stands a wealth of practical knowledge gained from years of experience and exhaustive laboratory and field research.

This extensive, specialized information forms a complete engineering library. It is available under single subject headings, as shown on the accompanying list, to any one qualified to make good use of it. Please use your company letterhead in mailing your request.

Personal consultation by New Departure engineers, an important step in assuring good bearing performance — is always available upon request.

Nothing Rolls Like A Ball

NEW DEPARTURE

BALL BEARINGS

(identify by code letters, please)

CODE Letter

BOOKS ON DESIGN

BA	Bearing Application (Part I)
DD	Details of Design (Part II)
EL	Enclosure & Lubrication (Part III)
LC	Bearing Load Computation (Part IV)
AP	Application Procedure (Part V)
LF	Full Scale Drawings of Bearings
H	Tables, formulae, bearing principles load computation, bearing installation

MAINTENANCE AND SERVICE

SP	Service Procedure for Ball Bearings
R	Interchangeable Replacement Bearings
RA	Rocker Arm Ball Bearings, Aircraft
SC	Bearing Service Wall Charts
FW	Front Wheel Adjustment Chart

GENERAL

S	Standard Catalog (Handbook, Vol. I)
BI	Explanation of numbering system
D	Sealed bearings (Discussion of Principles)
IB	Sealed Bearings with provision for relubrication
BM	How Steel Balls are Made
DE	Decimal Equivalent Tables (4 sizes)
T	Why Anti-Friction Bearings (Discussion of Fundamental Principles)
TT	The story of ball bearings in World War II

—and many other titles too numerous to mention. Tell us your needs.

REVOLUTIONARY ADVANCES IN WATTHOUR METER DESIGN

Completely new design, embracing new materials, new techniques, and ingenious methods has resulted in a meter with greatly improved performance and lower maintenance

By I. F. KINNARD

Manager of Engineering, Meter and Instrument Divisions
West Lynn Works, General Electric Company



I. F. Kinnard

MEASUREMENT of electrical energy has always been a vital factor not only in the development of the electrical industry, but also in the utilization of that energy by other industries. At the outset it was realized that widespread growth in electrification would require simple and equitable means of measurement.

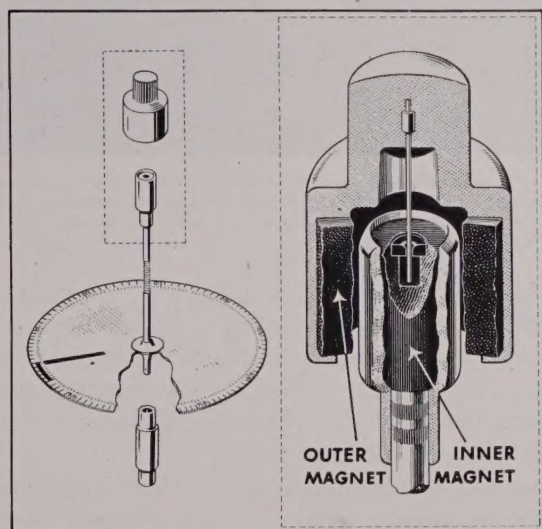


Fig. 1. Diagram of the magnetic-suspension arrangement in which two concentric magnets, magnetized axially with opposite polarities, support the moving system in equilibrium

Much of the early work of Edison was directed toward a means of replacing the first practice of measurement based on the number of electric lamps. In 1881 he introduced the chemical meter, which was used to measure ampere-hours in early direct-current systems of distribution. In 1889 production was started on the first commercial watthour meter in the form of the Thomson recording wattmeter, which was applicable to alternating or direct current. In 1894 the Shallenberger induction-type alternating-current watthour meter was introduced. While the later one half century of progress in the art of metering has been superseding designs, with progressive development and improvements, the fundamental induction principle has proved so well suited to the need that it has been used continuously throughout that period, and it is retained not only in

what has been the most modern watthour meter but also in the new meter described in this article.

The present-day watthour meter is a high-quality precision device. There are few, if any, commodities on the market that are measured more accurately than electrical energy. Not only do meters have a very wide load range from a starting load of one third per cent of rating to a maximum load of 400 per cent of rating, but they are temperature-compensated for the extreme ranges in temperature found out-of-doors and in northern and southern latitudes. Stability and life have been improved to the point that it is common practice for electric utilities to check meters only once every eight years. One naturally wonders what further improvements could be devised. However, in spite of the broad background and the excellent performance of the present-day meter, it has been found possible to develop a new single-phase watthour meter having new and outstanding features in all its components.

The major objective in this development has been to reduce maintenance. This has been accomplished through the use of a magnetically supported moving element and an over-all co-ordinated design wherein bearing maintenance has been eliminated and high accuracy and long life are assured. In keeping with the long bearing life, many advances in improved insulation and better corrosion resistance have been incorporated to give a long life without maintenance. Other advantages include improved performance and appearance, a reduction in size of 18 per cent, and a weight reduction of 30 per cent.

Magnetic Suspension of the Moving Element

The magnetic suspension of the moving element is the central feature of the new watthour meter. A small amount of magnetic material supports all the weight of the disk and shaft and eliminates the need for jewel bearings, which have been the main cause for meter maintenance. Much previous work with jewel bearings using pivots or balls and various materials and lubricants has not resulted in a complete solution.

The construction of the magnetic suspension is shown in Fig. 1. Two cylindrical permanent magnets of the high-coercive and machinable material cunco are placed one within the other (Fig. 2), the outer magnet being fixed to the meter frame and the inner magnet

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 11 to 15.—Ed.

attached to the upper end of the disk shaft. The rotating element is shown in position in **Fig. 3**. The concentric magnets are magnetized axially with opposite polarities. The resulting field supports the rotating moving system at a definite and small downward displacement.

To keep the moving system in line, stainless-steel guide pins are provided at the top and bottom. Graphite guide bushings at both ends of the shaft run on these guide pins without lubrication. The only possible cause of mechanical friction and wear in this system is the presence of side-thrust forces, and the design has been so made that these are inherently very low. This construction replaces the conventional bearing where the entire weight of the moving system and most of the side-thrust forces are supported in the jeweled lower bearing.

In the conventional jeweled bearing, the bearing stress due to the weight of the disk is of the order of 200,000 lb per sq in. In the magnetically suspended moving element, the bearing stress due to the weight of the disk is completely eliminated. Moreover, the torque-to-weight ratio, which has been long accepted as being in the order of 3 or 4 to 1, has been increased to infinity. This comparison in both cases ignores the secondary effects of side thrust.

Side-thrust Forces

With all the weight of the moving system supported magnetically, the only forces that could cause wear are side-thrust forces. In co-ordination with the use of the magnetic suspension, the meter structure has been arranged to keep the side-thrust forces low in value.

These forces arise from the action of the electromagnet and the damping magnet on the meter disk. In the conventional meter the electromagnet is mounted back of the frame and disk shaft, and the damping magnet is located at the front of the meter. The right-hand section of **Fig. 4** shows a top schematic view of the meter disk with the electromagnet on one side of the shaft and the damping magnet poles on the other side of the shaft.

Fig. 2. Close-up of the rotating element. The small cunio magnet at the upper end of the disk shaft is placed within the larger magnet. Interaction of the two magnetic fields supports the rotating system

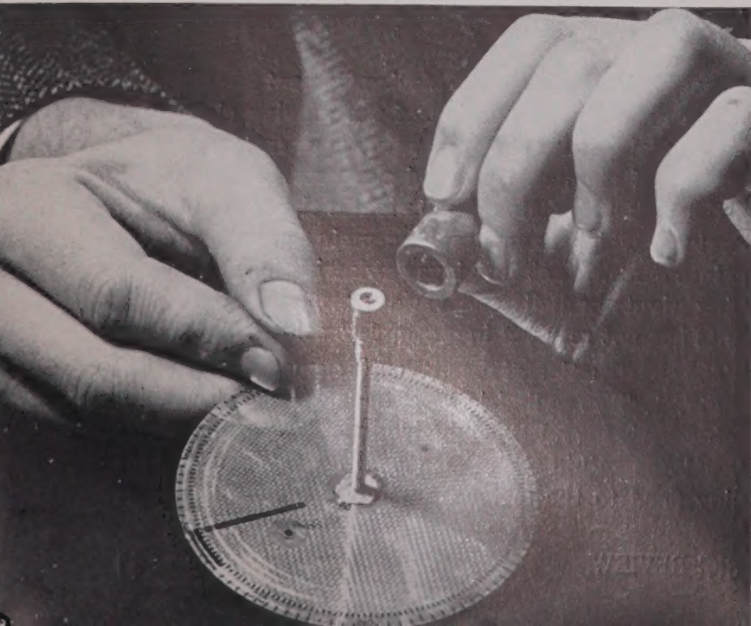


Fig. 3. The magnetically suspended rotating element is shown positioned in the frame. The vernier screw for full-load adjustment, shown to the right, operates a magnetic shunt that governs the speed of the rotating disk

When torque is created in the disk by a power load, this driving torque is equivalent to a side thrust at the location of the electromagnet. Motion of the disk causes a corresponding side thrust at the damping-magnet position. The total side thrust on the disk bearing is equal to the sum of these forces.

To completely eliminate side thrust would require placing the electromagnet and the damping magnets in the same location. In the new meter the large reduction in side thrust has been achieved by locating the damping magnets closer to the electromagnet than has been heretofore possible. Because the permanent-magnet poles are located nearer the electromagnet so that they create practically no net side thrust, the only significant side thrust present is that caused by the electromagnet, as shown in the left-hand section of **Fig. 4**. This pressure is in the order of 100 lb per sq in. at maximum load, which is conservative for the material involved and of a very different magnitude from the pressures found in conventional jewel bearings.

A second possible cause of side thrust in a moving system supported by magnetic suspension may arise in the magnetic suspension itself and occurs if the inner magnet is eccentric with respect to the outer magnet and increases with increased displacement. This condition was one of the causes of the failure of an early attempt to apply a magnetic suspension to a moving system. In this case the flux crowding due to the use of soft-iron pole pieces on the stator and rotor caused

considerable side thrust with the displacements encountered in manufacture and service. The present availability of the high-coercive-force alloy cunico has made possible the present design without soft iron and with only small stator and rotor magnets to give the necessary lifting force. As a consequence, and because

of the proportions used and precision manufacturing, the side thrust due to eccentricity is so small that it can be neglected.

Magnetic-suspension Life Tests

Development of the magnetic suspension was well under way before the war. It was progressed to the stage where it was applied to 194 single-phase watt-hour meters that were started on accelerated life tests in October, 1941. Since then these meters have been operating at varying loads on a daily cycle that gives about ten times normal registration, so that in nearly seven years the registration per meter has totaled normal registration of 65 years, or about 80,000,000 revolutions. This test has shown excellent stability of the magnetic suspension. At the same time it has served as a proving ground for the proper guide-bushing materials, many of which were tried and found satisfactory. Graphite and stainless steel were the final choice of several possibilities. The magnetic suspension with low operating pressures and no lubrication has proved to be the solution of the long quest of a maintenance-free bearing.

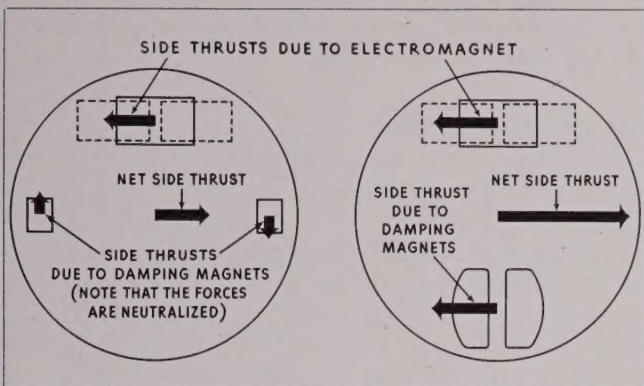


Fig. 4. Comparison of side thrust existing in the conventional meter (right) with that in the new design (left)

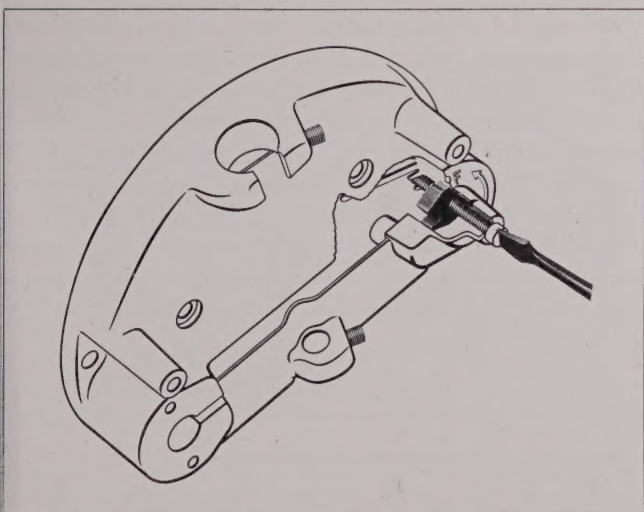


Fig. 5. Cutaway view of the one-piece aluminum-alloy frame showing the position of the damping magnets. At the right is the vernier magnetic shunt described in Fig. 3

Damping System

The damping system of the new meter consists of two small C-shaped magnets that are embedded as inserts in the die-cast aluminum-alloy frame, as shown in Fig. 5. The magnets make use of the high-energy and high-coercive properties of alnico 5, and, as a consequence, a large amount of damping is obtained in a small design. Die casting the magnets into position in the frame results in an assembly with the magnets fixed in position and surrounded by the aluminum die-casting alloy, which enhances the excellent surge-resistant properties of alnico 5. This combination, with the small size of the magnets, has made possible the location of the magnets near the electromagnet, and yet they are immune to demagnetization from fields that arise from large short-circuit or lightning currents to which meters are sometimes subjected.

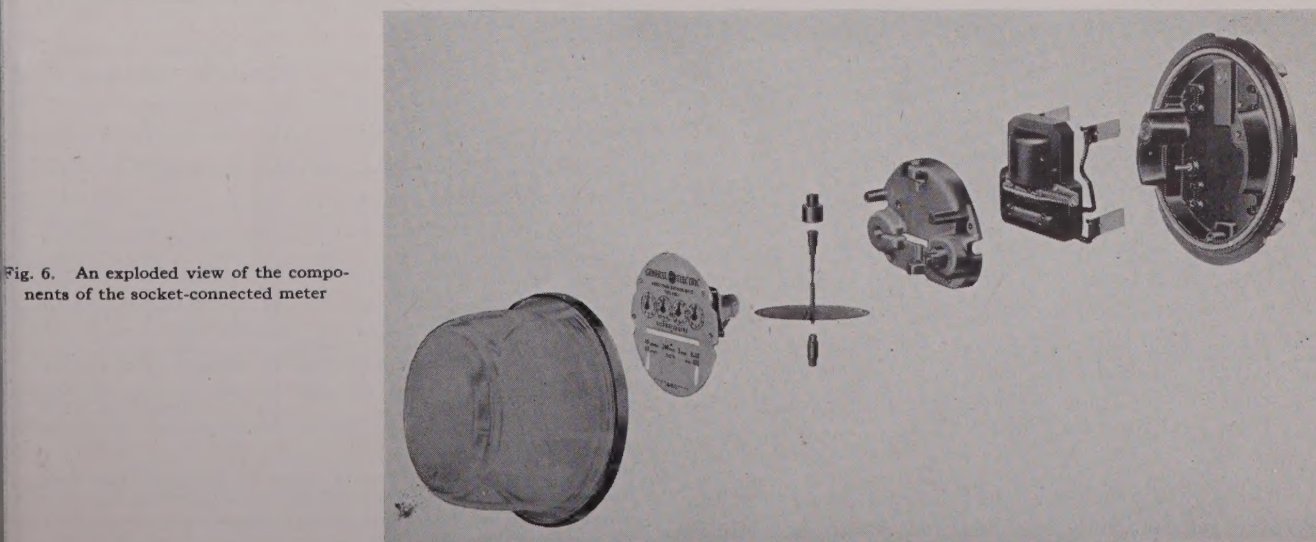


Fig. 6. An exploded view of the components of the socket-connected meter

As shown in Fig. 6, the frame provides excellent alignment and support for the magnetic suspension and the moving element. The electromagnet and register are also located accurately by being attached directly to the frame.

Electromagnet

The electromagnet (Fig. 7) is excited by line voltage and load current. It generates in the meter disk a torque proportional to the power load. The new electromagnet provides this torque efficiently to give inherently small load, voltage, frequency, power-factor,

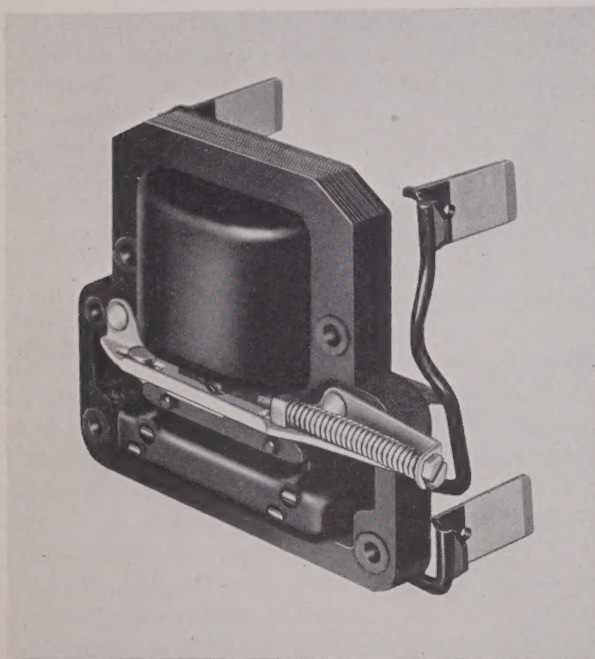


Fig. 7. The electromagnet as used in the socket-connected meter. The micrometer light-load adjustment can be seen to the right. Arrangement used in the bottom-connected meter differs from this assembly in that the horizontal terminals are replaced with vertical connectors that extend from the bottom

and temperature errors. The small inherent errors require only the minimum of compensation to provide the excellent operation shown in the characteristic curves (Fig. 8).

The excellent performance is accompanied by a new high insulation level compatible with the general practice of installing meters out-of-doors and ahead of service entrance fuses and switches. The current coils are formed of bare copper wire. For assembly they are located with the electromagnet core in a mold that aligns all parts with proper spacings. Butyl rubber is then introduced to the closed mold and is cured in place. The result is an accurately and securely located current coil with the rubber providing turn, coil, and ground insulation. This is in contrast to the usual practice of using taped or enameled wire for current coils. The turns of such wire had to be separated from each other and from the core, usually by some form of paper or fiber.

The butyl rubber has long-life properties even at the elevated temperatures to which meters are sometimes

subjected. The molded-coil construction also contributes to low temperature rise and high overload capacity because of efficient heat dissipation.

For greater insulation strength, reliability, and secure positioning, the layer-wound potential coil, consisting of many turns of fine wire, is similarly molded to the electromagnet core. The molding material in this core is a polyethylene plastic of high dielectric strength and low moisture absorption.

Calibration and Adjustments

The adjustments are co-ordinated with the design to give long-time stability of calibration and precise adjustment. The main full-load adjustment made at the factory is accomplished by demagnetizing the damping magnets in the meter frame to give the proper disk speed at rated full-load power on the meter. This is made to within one per cent. For the final precise calibration, the full-load vernier adjustment shown in Fig. 5 is used. This is a magnetic shunt that is moved to change the effective damping strength of the right-hand magnet.

The lag or phasing adjustment and the light-load adjustment are attached directly to the electromagnet (Fig. 7). The lag adjustment, which is made only at the factory, provides the required phase angle of the useful potential flux to give the proper registration at all power factors. Adjustment is accomplished by severing portions of the lag plate to change its resistance instead of moving it to change its effectiveness. This insures stability of calibration. A temperature-sensitive magnetic core is included on the lag plate to maintain the

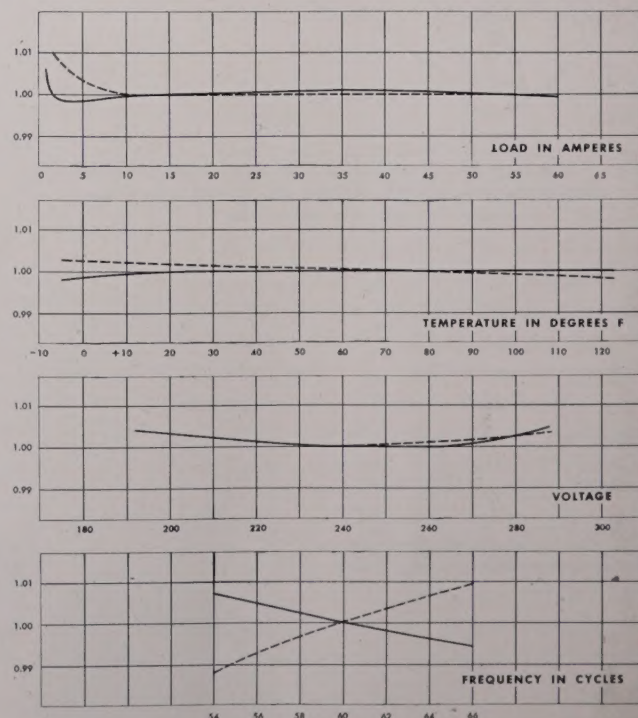


Fig. 8. Characteristic performance curves for the single-phase meter; operation at 1.0 power factor is indicated by the solid lines, and at 0.5 power factor by the dotted lines. Normal voltage was held constant for the load curve; current was held constant at 15 amp for the other curves

phase angle over the operating temperature range. The light-load adjustment consists of a closed conducting loop movable transversely with respect to the electromagnet to provide an adjustable shading-pole torque that enables adjustment at light loads to close limits. This adjustment and the full-load adjustment are inherently fixed, once made, to give good calibration stability.

Register

The register may be of the pointer type (Fig. 9) or the cyclometer type (Fig. 10). Both of the corresponding dials have been designed to give good legibility. The pointer-type register employs a time-proven double-worm-gear reduction, shown in Fig. 9 (b), and bearings of stainless-steel pins running in aluminum to maintain friction at a negligible value.

In the cyclometer register, friction has been greatly reduced by placing the number cylinders on vertical rather than horizontal shafts. A new arrangement employing magnetic storage and release of energy gives a positive reading action. Cylinders 2, 3, and 4 are advanced from digit to digit quickly as controlled by snap

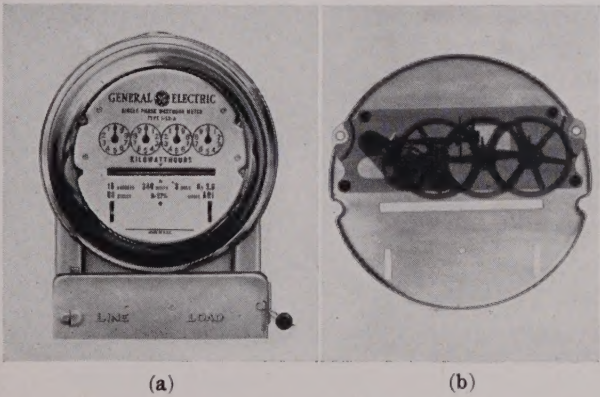


Fig. 9. Pointer-type register: (a) as used in the bottom-connected meter. (The appearance of the socket-connected meter is shown in Fig. 6); (b) an x-ray picture of the register gear mechanism

action occurring in the shaft assembly for Cylinder 1. Fig. 10 (b) shows the rear view of the cyclometer register and the Geneva gearing between cylinders.

Base and Cover Assemblies

When assembled with cover and with bottom-connected type of base, the new meter has the appearance shown in Fig. 9 (a). With socket or plug-in base for detachable installation, the appearance is that indicated in Fig. 6. Both types fulfill the various service requirements, including standardized mounting dimensions.

Much attention has been given to corrosion resistance. The socket-connected type of meter has a one-piece molded Textolite base and a cover ring of stainless steel. In the meter of the bottom-connected type all exposed metal parts are made of aluminum.

Both types incorporate co-ordination of insulation levels. Included with the socket-type base are ground straps that contact the socket when the meter is

installed. These are held to the base by rivets that project into the interior of the meter to form a controlled air-gap spacing between them and the line leads of the current coils. The voltage breakdown level of these relief gaps is lower than the high insulation level of the electromagnet. Thus overvoltage breakdown is directed to the point where it will do least damage, and

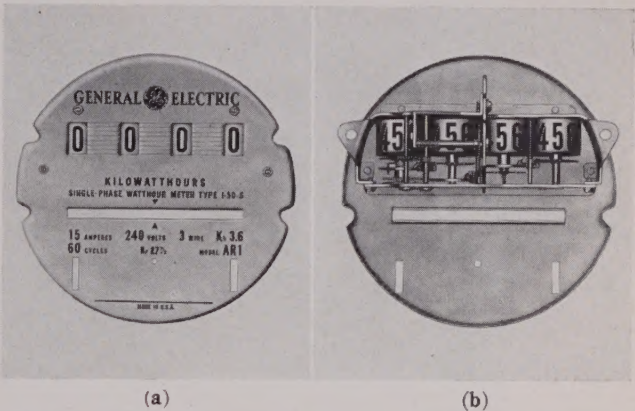


Fig. 10. Cyclometer-type register: (a) front view; (b) rear view, showing Geneva gearing between number cylinders

in most cases the meter will not be put out of service. A similar construction is employed in the bottom-connected type of meter, thus keeping breakdown away from the terminal block and also away from the electromagnet.

Summary

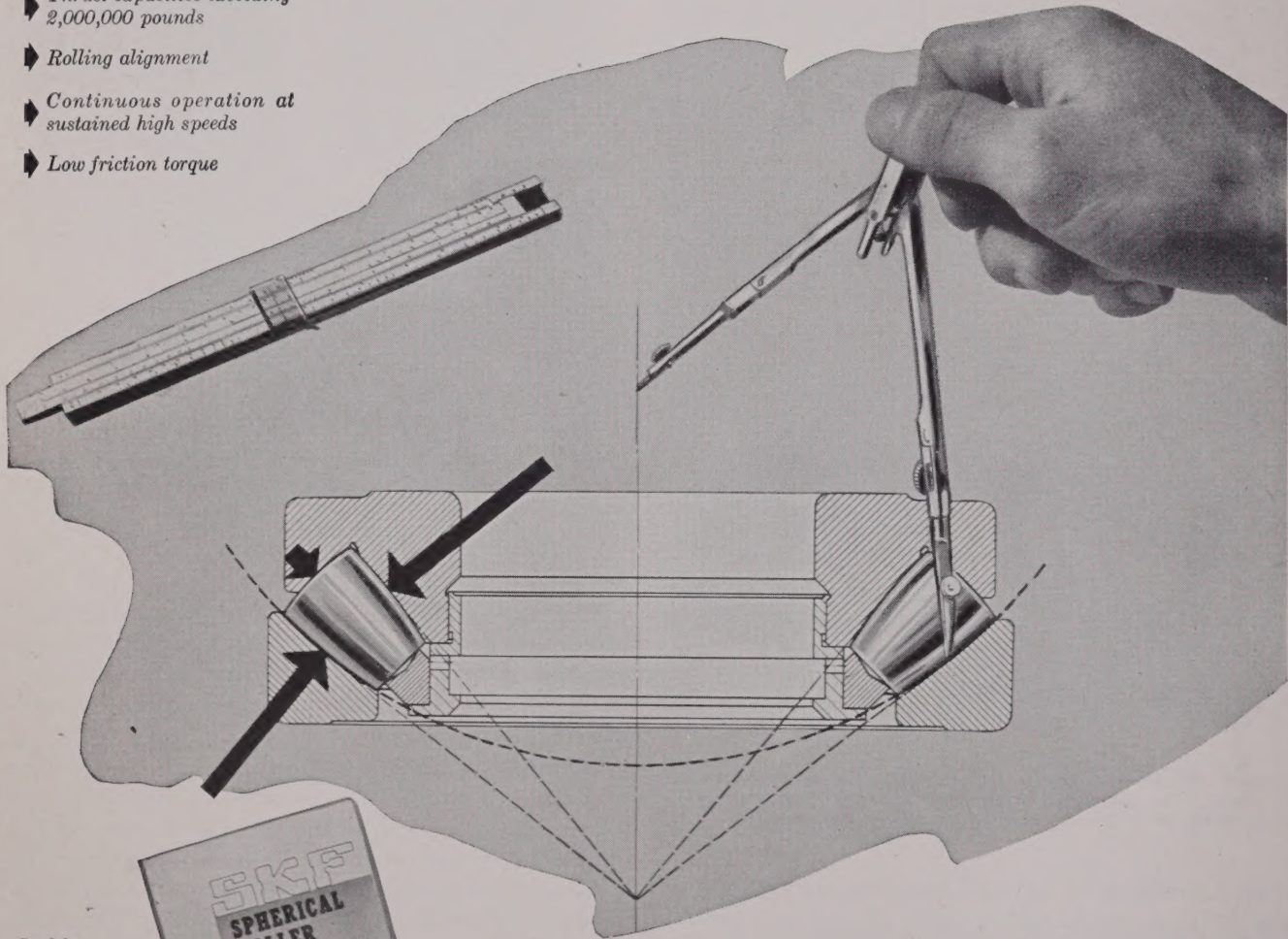
The true significance of the developments described in this article is that they have produced the first completely new meter in fifty years—new in its conception, its design, its operation, and in its use of modern materials and techniques.

Its magnetic suspension provides the answer to the long-standing quest for a lifetime bearing. This new suspension also places new emphasis on other design details, for the full benefits of the revolutionary moving system can be realized only in a meter having characteristics consistent with a lifetime bearing. Therefore, to take full advantage of the longer life of the moving system, the new meter has a radically new damping system, a more efficient electromagnet, and rigid unit construction of all parts. Also, to guard against abnormal operating conditions that shorten meter life, use is made of the most modern materials and techniques, as illustrated by the use of butyl-molded current coils and polyethylene-enclosed potential coils, and the co-ordinated insulation design which assures increased protection against damage by high-voltage surges.

Added together, the new design features and the new materials and techniques combine to provide stability of calibration over long periods of time. And they assure lower maintenance costs, greater ease in handling, and greater sustained accuracy than have ever been achieved previously in a watt-hour meter.

ENGINEERED BY **SKF** TO CARRY **HEAVY THRUST LOADS** *at high speeds!*

- ▶ Thrust capacities exceeding 2,000,000 pounds
- ▶ Rolling alignment
- ▶ Continuous operation at sustained high speeds
- ▶ Low friction torque



Send for
CAT. 279



The **SKF** Spherical Roller Thrust Bearing is designed to carry heavy thrust loads at sustained high speeds. This high capacity is not reduced by misalignment between shaft and housing bore, since the outer race of the bearing is a section of a sphere on which the inner race and spherical roller assembly align freely.

The rollers are so shaped that load components firmly contact the roller ends against the unusually high guide flange. This assures positive guiding of the rollers without excessive pressure on the roller ends.

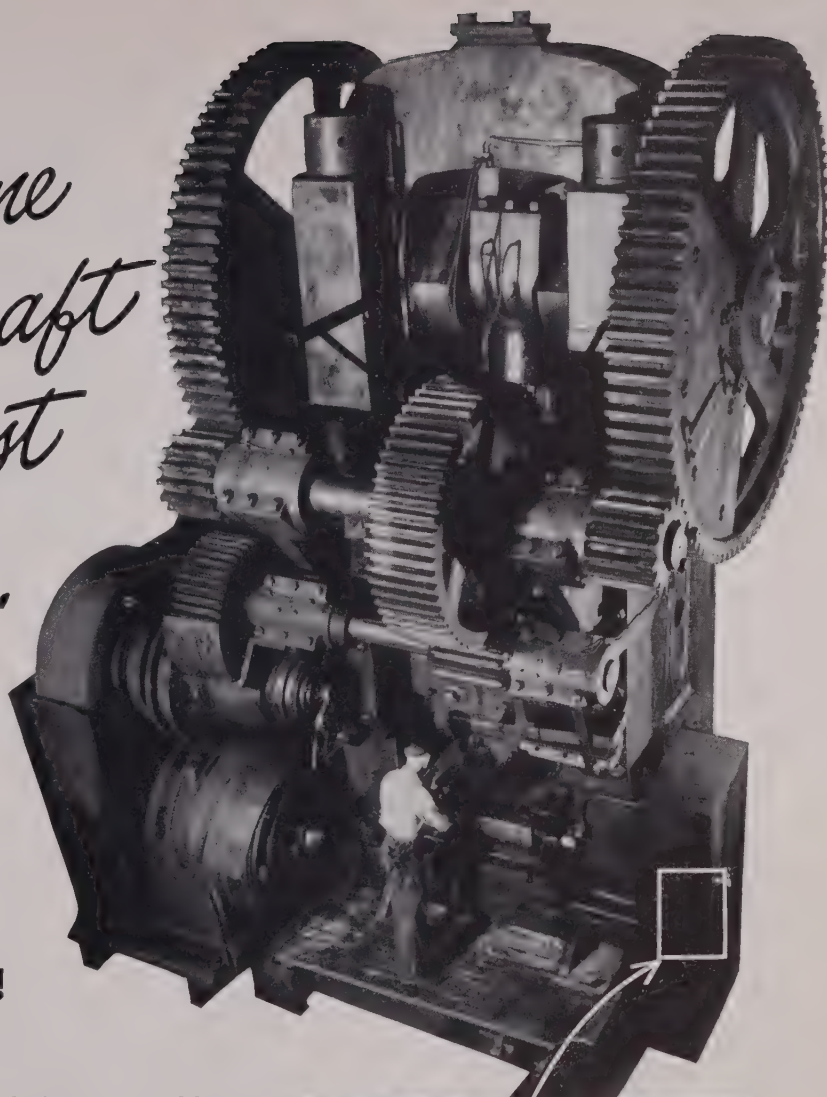
The bearing is so constructed that oil is pumped outwardly between the rollers, bathing all parts of the bearing in lubricant.

6454

SKF INDUSTRIES, INC., PHILA. 32, PA.

*Every time
the crankshaft
broke it cost
\$15,000...*

**Now Brush
Direct-Inking
Oscillographs
Chart each strain!**



At one of Cleveland's great steel plants, a problem needed solution . . . fast! When the strain was too much, the crankshaft of this forming press snapped—costing the company about \$15,000 each time. To analyze the strain of this giant 3 million pound press, Brush Direct-Inking Oscillographs were installed. Now every strain draws its own record on Brush graph paper *instantaneously*.

Instantaneous, permanent, ink-on-paper recordings by Brush Oscillographs make their use almost unlimited. Accurate recordings of strains, pressures and countless electrical phenomena can be made over a frequency range of D.C. to 100 c.p.s. Either A.C. or D.C. signals can be measured. Whenever desired, recordings may be stopped for notations on chart-paper.

Write today for detailed information on this equipment.



Two Brush Double-Channel Oscillographs check the load at each corner of this huge forming press. Chart record is *instantaneous*.

THE **Brush**
DEVELOPMENT CO.

3405 Perkins Avenue • Cleveland 14, Ohio, U.S.A.

MAGNETIC RECORDING DIV. • ACOUSTIC PRODUCTS DIV.

INDUSTRIAL INSTRUMENTS DIV. • CRYSTAL DIVISION

Canadian Representatives: A. C. Wickman (Canada) Ltd., P. O. Box 9, Station N, Toronto 14

A black and white portrait of a middle-aged man with dark hair, wearing glasses, a white shirt, a patterned tie, and a dark suit jacket. He is looking slightly to the left of the camera with a neutral expression. The background is dark and out of focus.

H. S. Gode

A black and white portrait of a middle-aged man with a receding hairline, wearing a dark suit, white shirt, and patterned tie. He is looking slightly to the left of the camera with a neutral expression. The background is dark and out of focus.

Locke H. Burnham

L. H. BURNHAM, Power Transformer Division, Pittsfield Works
General Electric Company

shutting off the master controller. The reasons for this will be explained later in this article.

The continuous tractive-effort rating in the low-speed connection is 119,000 lb up to a speed of 15.75 mph, where the horsepower curve of the synchronous motor is reached, as shown in **Fig. 2**. Similarly, **Fig. 3** shows that in the high-speed connection with series excitation for the traction motors, the tractive-effort rating is 82,500 lb up to 22.8 mph. By making use of the separate excitation connection of the traction motors in the

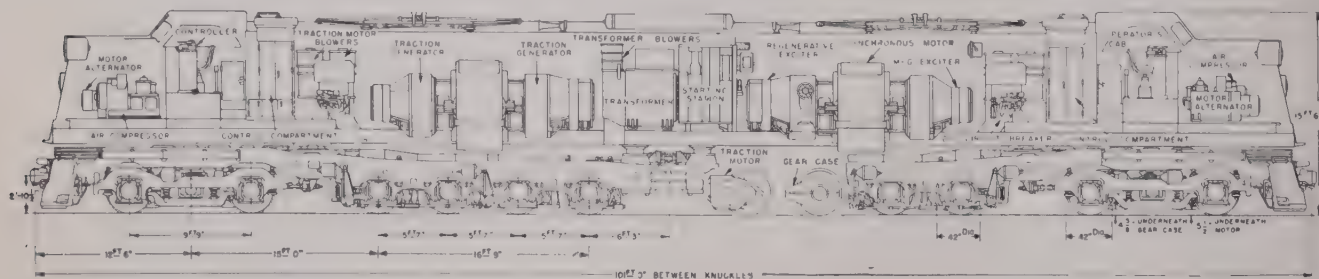


Fig. 1. Sectional view of 5000-hp electric locomotive showing location of principal apparatus

high-speed connection, the traction motors can be excited up to their full field strength without overloading the main generators. This permits the traction motors to be operated at 90,000 lb tractive effort up to a speed of 21.9 mph.

In **Fig. 4** the high-speed-connection performance with the traction motors separately excited is given; and, similarly, **Fig. 5** gives the characteristic in the low-speed connection. By referring to these curves, it will be noted that an "area curve" gives the limits of operation. Certain important characteristic elements of the control system have been indicated, such as:

- (1). A typical main-handle and separate-excitation-handle notch throughout the whole operating range from motoring to braking and back to motoring again.
- (2). The horsepower limitation, continuous, which is 5000 motoring and 5750 braking at the rail.

The curves with the fixed-main-handle and separate-excitation-handle positions illustrate how the system will float from motoring to braking even without lever manipulation by the operator. The condition of motor-

This article is so paged that, without other articles, it can be conveniently removed for separate filing on pages 18 to 23.—Ed.

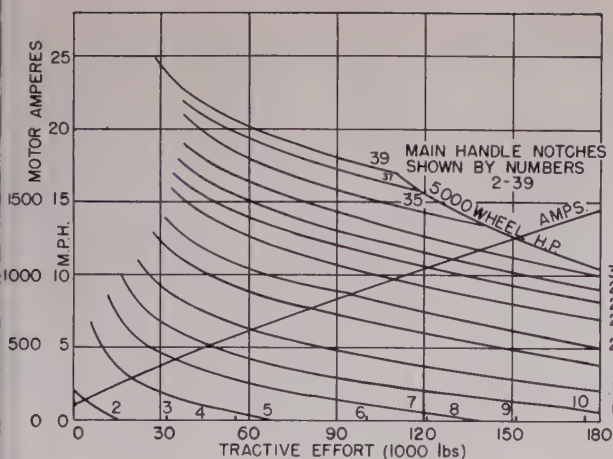


Fig. 2. Locomotive characteristic curves with low-speed connection for series-excited traction motors

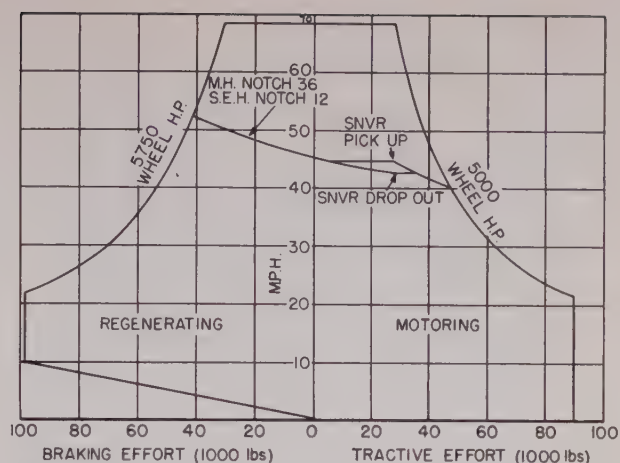


Fig. 4. Locomotive characteristic curves with high-speed connection for separately excited traction motors

TABLE I

PRINCIPAL DATA AND DIMENSIONS OF THE 5000-HP GREAT NORTHERN LOCOMOTIVES

Wheel Arrangement.....	B-D + D-B
Total Weight.....	720,000 lb
Weight on Drivers.....	720,000 lb
Number of Driving Axles.....	12
Weight per Driving Axle.....	60,000 lb
Continuous Rating	
At Rail.....	5000 hp
Tractive Effort.....	119,000 lb
Speed.....	15.75
Adhesion.....	16.5 per cent
Starting Tractive Effort	
25 per cent Adhesion.....	180,000 lb
Maximum Operating Speed.....	65 mph
Number of Traction Motors.....	12
Gear Ratio.....	70/17
Line Voltage.....	11,000
Phases.....	Single
Cycles.....	25

Air-brake Equipment.....	Straight and automatic
Number of Compressors.....	2
Compressor Air Capacity (Total).....	300 cfm
Type of Control.....	Electro-pneumatic
Minimum Curvature—Coupled to Train.....	10 deg
Minimum Curvature—Locomotive only.....	17 deg
Length Over-all, between Knuckles.....	101 ft 0 in.
Total Wheel Base.....	85 ft 9 in.
Rigid Wheel Base.....	16 ft 9 in.
Width Over-all.....	11 ft $\frac{3}{8}$ in.
Height over Pantograph, Locked Down.....	16 ft 0 in.
Driving Wheel Diameter.....	42 in.
Height over Cab.....	15 ft 6 in.
Width over Handrails.....	11 ft $\frac{3}{8}$ in.
Width over Cab.....	10 ft $4\frac{3}{8}$ in.
Track Gage.....	4 ft 8 $\frac{1}{2}$ in.
Coupler Height.....	2 ft 10 $\frac{1}{2}$ in.
Clearance over Rail, New Wheels.....	4 $\frac{5}{8}$ in.

ing or braking is determined solely by locomotive speed relative to the particular controller-handle positions. If the locomotive speed is high relative to these positions, the locomotive will be exerting braking effort.

If the locomotive speed is low relative to these positions, the locomotive will be exerting tractive effort. Although there is the tendency for a given controller-handle setup to maintain a constant locomotive speed, this characteristic is not so pronounced as to be objectionable from a train-handling viewpoint. The

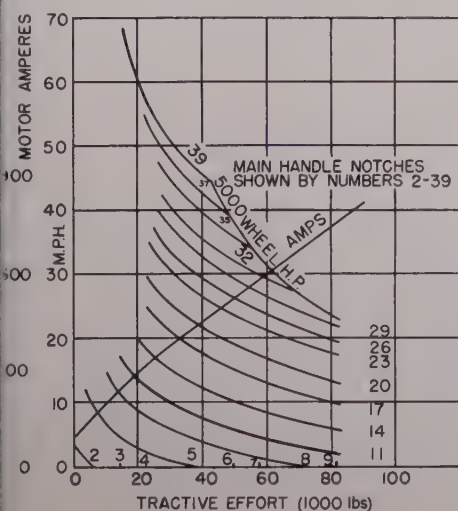
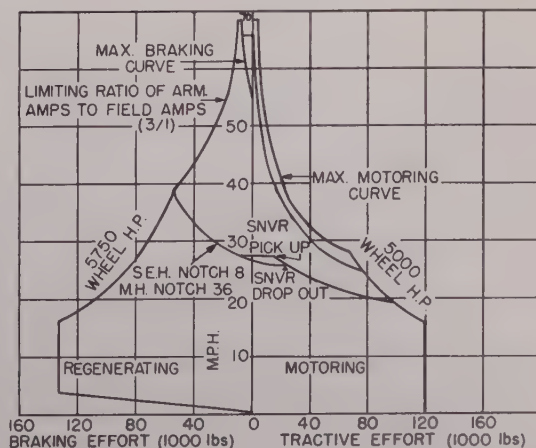


Fig. 3. Locomotive characteristic curves with high-speed connection for series-excited traction motors

Fig. 5. Locomotive characteristic curves with low-speed connection for separately excited traction motors



curves show a substantial increase in speed from the maximum tractive effort motoring to maximum braking effort in braking, an effect that is well in accord with the operating requirements of the railroad.

Also in Fig. 5 the characteristic of being able to develop full braking effort down to 3.5 mph is shown. The main-generator voltage control is reduced to zero shunt-field strength in the first main-handle notch; thus, braking can be maintained down to standstill without the locomotive passing over into motoring. Such precise control is particularly desirable in mountain freight service, for it permits holding maximum braking effort down to the speed of a walk. When a full stop is desired, a slow application of the locomotive independent air brake can be made without shutting off the controller. This is useful in stopping for siding when going downgrade. A brakeman can then run ahead and open the switch without the necessity of the engine-man applying train brakes for controlling train speed and without resultant possibility of rough handling.

POWER APPARATUS

The principal units of electric equipment are listed in Table II. All rotating equipment is especially designed for railroad service and is provided with Class B insulation throughout.

Main Transformers*

Each locomotive is equipped with the latest development in power transformers, such as the one shown in Fig. 6. This 25-cycle 4969-kva transformer, stepping

*By L. H. Burnham, Power Transformer Engineering Division, General Electric Company, Pittsfield, Mass.

from 11,000 to 1350 volts, is filled with Pyranol insulating and cooling liquid. Oil-filled transformers frequently are used for other types of power service, but they generally are considered undesirable for locomotive service because of the fire hazard. However, Pyranol insulation liquid is nonflammable; hence, a transformer filled with this liquid is ideal for locomotive service. In addition to being nonexplosive and nonoxidizing, Pyranol insulation has all the good qualities of mineral insulating oil, including high dielectric strength, stability, low freezing point, and low viscosity. Consequently, the Pyranol type transformers have numerous advantages for use on electric locomotives including:

- (1). Low maintenance
- (2). High dielectric and impulse strength
- (3). High overload capacity
- (4). Long life due to uniform temperature throughout the winding
- (5). Nonflammable
- (6). Nonexplosive
- (7). Ability to stand much abuse
- (8). Ability to carry heavy overloads
- (9). Nonsludging.

When cooling the transformers, the hot Pyranol liquid is forced through the cooler tubes in turbulent flow, while a blast of air is blown across the external tube surface which is finned to increase the heat dissipation. These cooler tubes are made of seamless rust-resistant steel with copper fins wound and bound tightly around the

TABLE II
MAJOR POWER COMPONENTS OF THE 5000-HP GREAT NORTHERN LOCOMOTIVES

Apparatus	Quantity	Rating							Ventilation	Nomenclature in Circuit Schematic Diagrams	Special Features
		Cycles	Phase	Volts	Amperes or Kva	Poles	RPM	Output HP			
Main Transformer	1	25	1	11000/1350	4969 kva				Forced		Pyranol Type Forced Circulation
Synchronous Motor	2	25	1	1350	2490 kva 1.0 PF	4	750	3000	Self	ASI-1 ASI-2	
Main Generator	4	D-c		700/450	1500/2300 amp	12	750		Self	G1A, G1B, G2A, G2B	
Regenerative Exciter	2	D-c		25	3200 amp	16	750		Self	RE1, RE2	
Main Exciter	2	D-c		45	700 amp	6	750		Self	E1, E2	
Traction Motors	12	D-c			1050 amp	4		420	Self 2300 cfm	M1 to M12	
Compressor	2	25	1	150	240 amp	6	1170	38	Forced	C1, C2	150 cfm displacement at 135 psi
MA Set Induction Motor	2	25	1	235	335 amp	2	1476	85	Forced	ACM1, ACM2	
MA Set Alternator	2	123	3	275	131 amp	10	1476		Forced	A1, A2	
Control and Starting Generator	2	D-c		75	100 amp	6	1476		Forced	SG1, SG2	
Traction Motor Blowers	4	123	3	275	56 amp	4	3630	26			Axial Flow 10,000 cfm at 9.0" H ₂ O
Transformer Blower	2	123	3	275	16 amp	4	3610	7.5			Axial Flow 4500 cfm at 6.0" H ₂ O
Pantograph Collector	2										2-Shoe, Lubricated

ibes. This whole air-side surface is then tinned to obtain a perfect bond between the fins and the tubes and also to make the surface perfectly rust resistant. All the liquid coolant is circulated through the cooler about once every minute. Cooling in this manner is so effective that it made possible the reduction of the transformer's size and weight to the minimum, an especially desirable feature for railroad service.

The turbulent flow of liquid across the coil and tube surfaces reduces the temperature of the hot spot to a value nearer that of the average winding temperature. Thus, the temperatures are more nearly uniform throughout the windings. Such temperature distribution reduces aging of the insulation and permits heavier short-time overloads on the transformer. The assembled core and coils showing the construction of the windings is illustrated in Fig. 7.

A 230-volt 25-cycle single-phase capacitor-type induction-motor unit, shown at the upper right in Fig. 6, drives a pump which forces Pyranol liquid through the windings and the cooler. This unit is immersed in the coolant, thereby eliminating external piping and the necessity for a stuffing box.

The windings of the pump motor are effectively cooled by the forced flow of Pyranol liquid. This pump-and-motor unit can be installed or lifted out by removal of only a few bolts.

The cooling air is forced downward and across the finned tubes by two axial-flow fans, mounted on top of the cooler, each driven by a three-phase 120-cycle 3600-rpm motor. Each fan delivers 4500 cfm of air at 1½ inches water pressure.

The 11,000-volt circuit is protected by a Thyrite restorer mounted on top of the cover adjacent to the high-voltage bushing to which it is connected, as shown in Fig. 6.

To obtain a thoroughly tight seal, the cover is welded to the tank, a type of construction that is standard practice for Pyranol type transformers in railroad service. Internal pressures due to temperature changes are controlled by a sealed air-compression chamber on top of the cover (Fig. 6). The pressure relief is mounted on the side of the air-compression chamber and consists of a frangible diaphragm that will rupture when an internal failure occurs and develops pressure inside the tank. This relief is shown in the upper left of Fig. 6. The total weight of the transformer including tank, windings, and liquid is 30,000 lb.

Main Motor-generator Sets

Each of the main motor-generator sets consists of a synchronous driving motor in the center flanked by two main d-c generators (Fig. 1). An exciter is overhung on the outside or commutator end of each main generator. One exciter of each set is the regenerative exciter, which furnishes excitation for the traction motors when required. The other is the main exciter, which supplies the excitation requirements for the synchronous motor, the d-c generator, and the other exciter. All machines of the sets are self-ventilated.

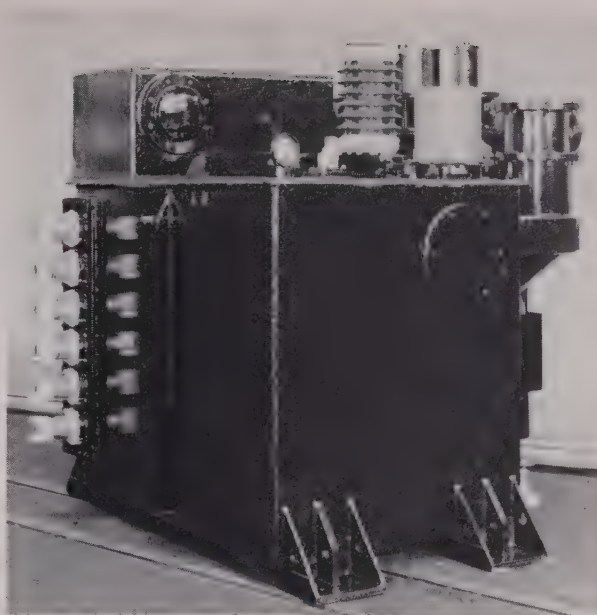


Fig. 6. External view of high-voltage end of main transformer. Low-voltage bushings are at left side of case

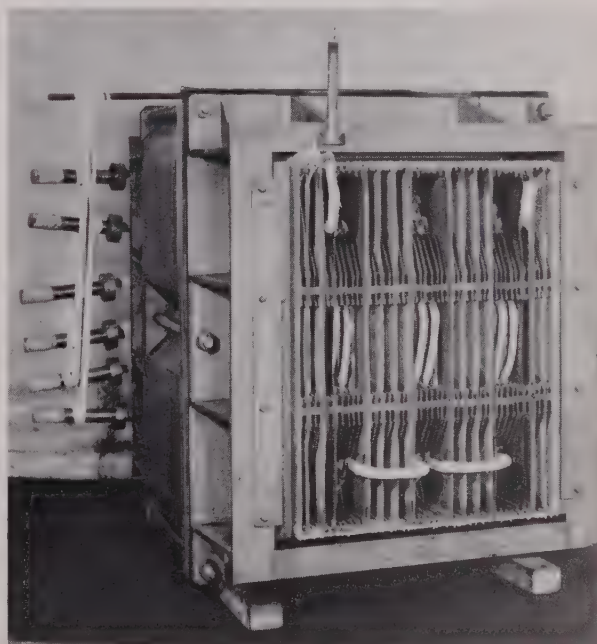
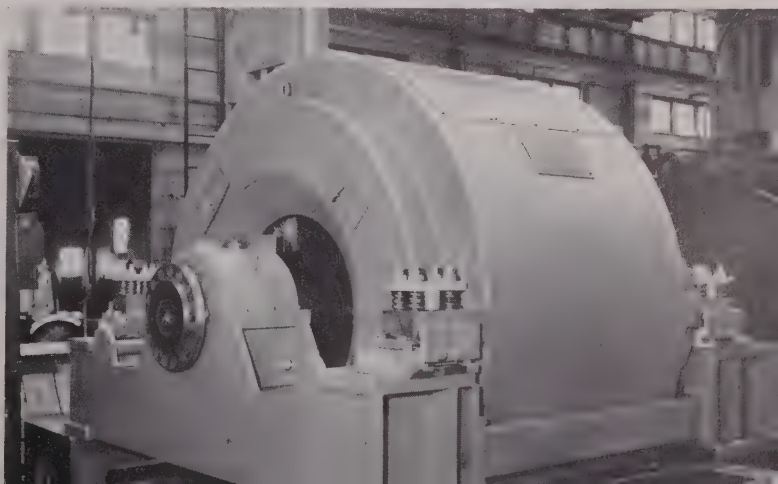


Fig. 7. High-voltage side of main transformer, showing core and coils

Fig. 8. Synchronous motor before installation in locomotive cab, showing spring mounting of stator



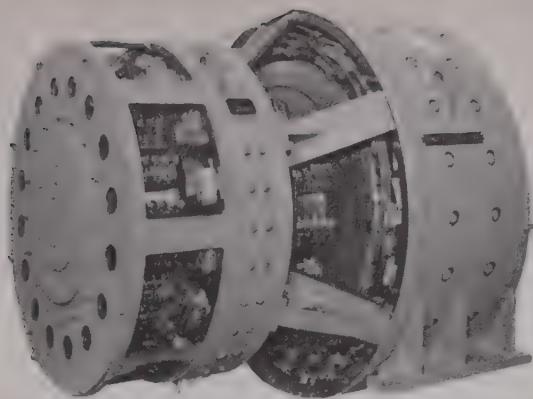


Fig. 9. Main generator and regenerative exciter (mounted at left) with commutator covers removed

The synchronous motor is shown in Fig. 8. To minimize the cyclic power pulsations occasioned with single-phase 25-cycle power, the stator is spring-mounted upon a base which forms a part of the cab structure. The four-pole rotor runs in sleeve bearings which are lubricated with disk-type oilers. The disks dip into the oil reservoir of the bearing, and a wiping arrangement removes oil from the disk on the top of the bearing, causing this oil to fall into the oil passages on the upper half of the bearing.

The motor is wound with temperature detectors embedded in the windings, and the hottest detector on each motor, as determined by test, is connected to a selector switch and indicating instrument in the No. 1 end of the locomotive. A shaft-driven overspeed switch is mounted on one of the main bearings.

The synchronous motors drive the generators (Fig. 9 and Fig. 10) through flexible disk couplings. The outer supports and bearings for the generator armatures are grease-lubricated spherical roller bearings supported by the generator frames.

The exciter armatures have a taper fit on the shaft extensions of the main generators. Mounted in a large cavity under the commutator of the regenerative exciter is a mechanical speed switch that is used during the starting sequence for determining the speed at which the alternating current should be applied to the synchronous motor.

Auxiliary Motor-alternator Sets

Each of the two auxiliary motor-alternator sets (Fig. 11) consists of a driving motor on one end, a 123-cycle 260-volt alternator in the middle, and a 75-volt battery-charging and main-set starting generator on the other end. A mechanical speed switch is mounted on the outside end of the driving motor. The sets are cooled by air taken from the main-motor ventilating ducts.

Traction Motors

The twelve traction motors (Fig. 12) are essentially duplicates of certain other traction motors used in railroad diesel-electric service. This motor is used on

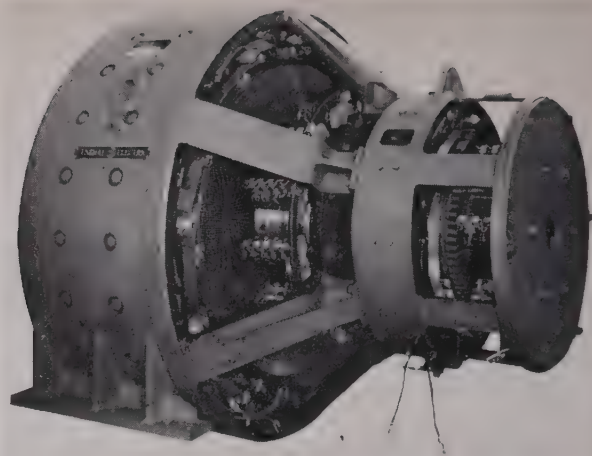


Fig. 10. Main generator and main exciter (overhung at commutator end) with commutator covers removed

the Great Northern units which have a 42-in. wheel and 70/17 gear reduction, giving a maximum permissible speed of 65 mph.

The grease-lubricated armature bearings are of the cylindrical roller-bearing type. The end thrust is taken on the commutator end with a bearing having flanged outer and inner races. The axle bearings are of the sleeve

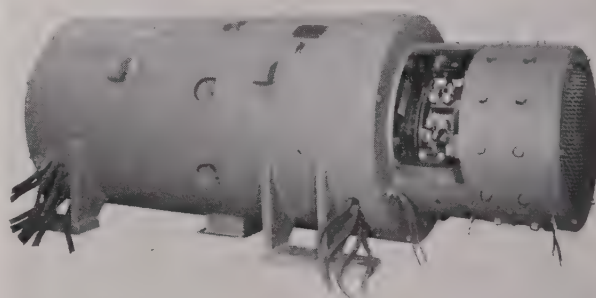


Fig. 11. Auxiliary motor-alternator set, with auxiliary d-c generator at right, for main-set starting and battery charging

type having long fiber-wool waste to lift the oil from the box to the axle. These bearings are equipped with the constant oil-level feature to give maximum mileage between lubrications.

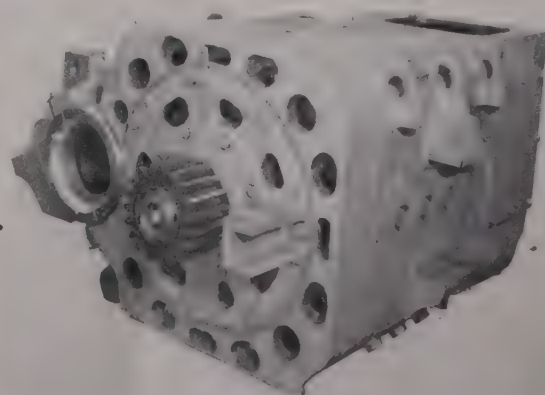


Fig. 12. Traction motor, showing pinion, axle lining, and nose for supporting motor in truck

Ventilating Equipment

The ventilating equipment consists of four 26-hp and two 8-hp 123-cycle 260-volt induction motors, driving axial-flow fans (Fig. 13). The motors are vertically mounted and equipped with grease-packed ball bearings. This equipment is used for ventilating the traction motors, stabilizing resistors, motor-alternator sets, and air compressors.



Fig. 13. Vertical axial-flow blower for transformer cooling

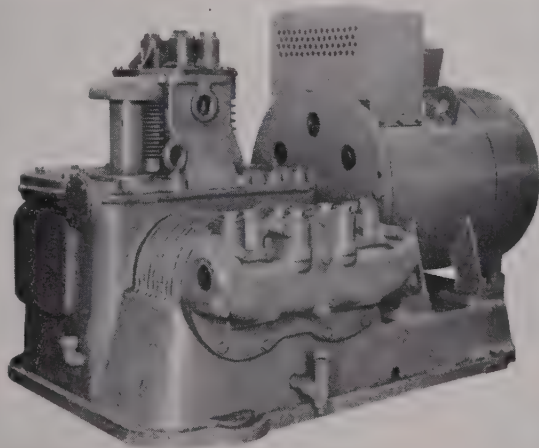


Fig. 14. A 150-volt 25-cycle two-stage air compressor

Air Compressors

The air compressors are of the reciprocating two-stage type, driven by a 150-volt 25-cycle series-wound commutator motor, as shown in Fig. 14. The motor frame is bolted directly to the compressor crankcase and drives the compressor by means of a worm drive.

Pantographs

Pantographs are of the spring-raised air-lowered type. They have been equipped with the railroad company's standard shoe with provision for lubrication.

(To be continued)

ASSOCIATED ELECTRICAL INDUSTRIES LIMITED



British Thomson-Houston Co. Ltd.

Edison-Swan Electric Co. Ltd.

Ferguson, Pailin Limited

Harcourts Limited

Hotpoint Electric Appliance Co. Ltd.

*(Incorporating International Refrigerator Co. Ltd.
and Premier Electric Heaters Ltd.)*

**Metropolitan-Vickers
Electrical Co. Ltd.**

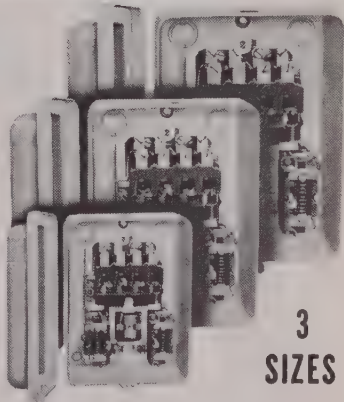
Metropolitan-Vickers-G R S Ltd.

Agents and Licensees of the
GENERAL ELECTRIC Co., U.S.A.
for the United Kingdom.

**NEW! WARD LEONARD
MOTOR STARTERS**

Here's a new line of a-c Magnetic Starters by Ward Leonard for positive and dependable across-the-line starting of nonreversing motors. Small in size, big in performance!

Unit construction. Open or enclosed type. Accessible components. Double-break silver-to-silver main contacts. Local or remote control. Sizes 1, 2 and 3.



**3
SIZES**

For full information send for Bulletin 4110. Ward Leonard Electric Co., 62 South Street, Mount Vernon, N. Y. Offices in principal cities of U. S. and Canada.

WARD LEONARD ELECTRIC CO.
Result-Engineered Controls
RESISTORS • RHEOSTATS • RELAYS • CONTROL DEVICES

A QUIET REVOLUTION IN CAPACITOR DESIGN

THE SMALLEST MOLDED
TUBULAR EVER MANU-
FACTURED! . . .
and rated up to 125° C!

A PROVEN PRODUCT NOW
IN MASS PRODUCTION!

ACTUAL SIZE
ILLUSTRATION
TYPE 65P

UNIQUE, MINERAL-
FILLED MOLDING MA-
TERIAL! . . . Provides
unequalled protection
against moisture absorp-
tion even under condi-
tions of extreme humidity!

Seven Physical Sizes		Color-Coded and Available in 20%, 10% and 5% Decade Values			
		TABLE OF MAXIMUM NOMINAL CAPACITIES			
	Mold Size	100V @ 125° C.	200V @ 85° C.*	400V @ 85° C.	600V @ 85° C.
65 P	.175" D. x 1-1/16"	.015	.01	.0068	.0022
	.195" D. x 1-1/16"	.022	.015	.01	.0033
	.250" D. x 1-1/16"	.047	.033	.022	.0068
	.375" D. x 1-1/16"	.15	.1	.068	—
75 P	.175" D. x 3/4"	.0068	.0047	.0033	.001
	.200" D. x 3/4"	.01	.0068	.0047	.0015
	.250" D. x 3/4"	.022	.015	.01	.0033

* alternate rating 150V @ 125° C.

NEW SPRAGUE MOLDED PROKARS*

... dependable capacitors for sub-miniature assemblies

**SUB-MINIATURE PAPER CAPA-
CITORS IN METAL CANS WITH
HERMETIC, GLASS-TO-METAL SEAL**

for the most severe applications

Yes, this little can houses a high quality hermetically sealed Paper Capacitor! Rated at 100 volts, D C Working, this .5 mfd. unit measures .4" x 1 1/4". Presently being manufactured in quantity, variations of this sub-miniature type can be made to your specifications. Write for complete information about this and even smaller hermetically sealed units now in production as shown below.

These new molded Prokars were designed specifically to satisfy stringent military requirements. Types 65P & 75P are now in mass production and are available in a wide range of capacities—from .00047 mfd. to .15 mfd! Though higher in price than standard units, they easily justify the term "premium" in performance. Rated for —50° C to 125° C operation, these small but rugged units are ideally suited for any electrical or electronic application in which size, temperature, humidity and physical stress are dominant considerations.

Write for Engineering Bulletin No. 205 A

*T. M. Reg. U. S. Pat. Off.

SPRAGUE

SPRAGUE ELECTRIC COMPANY,
NORTH ADAMS, MASS.

PIONEERS OF

ELECTRIC AND ELECTRONIC PROGRESS

RADIO-FREQUENCY RESISTANCE METER

Unusual circuit obtains effective resistance and other operating parameters more directly and with greater accuracy than has been possible with previous devices

By H. W. KLINE

General Engineering and Consulting Laboratory
General Electric Company



Halsey W. Kline

THE increasing need for more information about the performance characteristics of components used in radio-frequency networks has led to the development of a new meter for determining the operating parameters of coils, capacitors, and resistors, as well as antenna resistance and some transmission-line characteristics, over a band of 50 kilocycles to 85 megacycles. The radio-frequency resistance of such components can now be determined from the scale readings of an indicating instrument rather than as ratios of reactances to resistances.

Previous loss meters have required that a voltmeter of some form be connected directly across the component to be tested. The loading effect of such a device is questionable, particularly at frequencies above a few megacycles or when the parallel resonant impedance of a component is of high value.

The loss meter (Fig. 1) described in this article employs a low-impedance Wheatstone bridge having

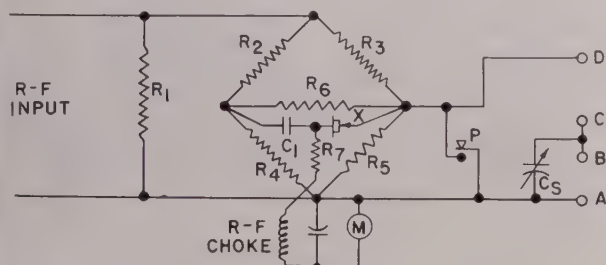


Fig. 1. Circuit diagram of the new r-f resistance meter

a microwave crystal-detector indicator circuit, the functioning of which will be described later. As a result of measuring effective resistance directly, rather than the ratio of reactance to resistance, or Q , no parallel loading of the component under test is necessary, resulting in a meter of high stability and accuracy. Variations in effective resistance of the test circuit therefore cause variations in the bridge leg impedance. Thus no extraneous loading of the components to be tested is required.

Past experience has shown that when the ratio arms of a Wheatstone bridge are composed of high-impedance components, it is extremely difficult to operate the

bridge at high frequencies with a high degree of reliability. Stray capacitances, leakage resistances, and residual inductances cause changes in the values of the bridge components. As the resistances of the ratio arms is decreased to comparatively low values, a high order of stability at higher and higher frequencies has been obtained. This was found to be particularly true in the case of low-impedance bridges having ratio arms of equal resistances. The problem presented in employing a bridge having fixed-ratio arm impedances was to operate it without using reactive components in at least one arm of the bridge.

Circuit Arrangement

Equal resistances form the bridge arms, R_2 , R_3 , R_4 , and R_5 (Fig. 1). The input impedance of the bridge is, therefore, equal to one leg resistance. The resistor R_6 , connected across the ratio arms, is of lower value. The r-f voltage, caused by bridge unbalance, appearing across R_6 is rectified by the crystal detector X . Capacitor C_1 is used as a d-c blocking capacitor. Resistor R_7 adjusts the voltage sensitivity of the d-c microammeter M . The internal standard capacitor is C_s .

Normally, a bridge is balanced with any frequency of input. The operation in this instance, however, is reversed. Instead of being balanced to null, as is the conventional method in operating bridges, the bridge is operated from a point of maximum unbalance. The pushbutton P is used to short-circuit arm R_5 of the bridge so that an adjustment of the input energy to the bridge by a zero-set control may cause the indicating instrument to read full-scale, the resistance-scale zero being at the right end.

The short-circuiting of R_5 is equivalent to placing an unbalancing load on the bridge having zero r-f impedance; hence the reference, or zero resistance, point is established on the instrument scale. This point is also an index of the correct input voltage, at any frequency, applied to the bridge.

If the bridge input impedance were allowed to remain as high as the leg resistance, depressing pushbutton P would result in poor r-f voltage regulation at the bridge input. However, with R_1 a low value of resistance (about 10 per cent of R_5), good r-f regulation results regardless of what happens across arm R_5 , and thus a source of error is eliminated.

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 25 to 30.—Ed.

The scale of instrument *M* is marked directly in r-f ohms; its appearance is indicated in Fig. 2. The method for calibrating the scale is as follows: The oscillator frequency is adjusted to some value at which the desired accuracy can be obtained with an available decade re-

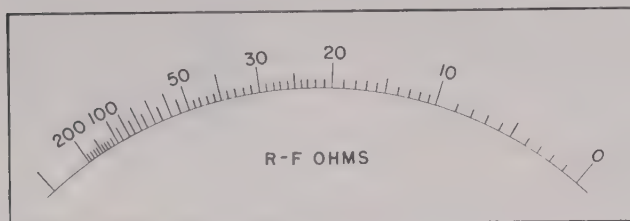


Fig. 2. Scale distribution of the indicating instrument

sistance standard. The zero of resistance-indicating instrument *M* is actually a full-scale value and is set by adjusting the level from the internal oscillator with the standard connected to terminals *A* and *D* and set at zero resistance. The resistance scale may be readily checked at any time by adding increments of resistance across R_5 ; the microammeter *M* will then deflect counter-clockwise. This scale distribution as shown in Fig. 2 is relatively insensitive to variations of crystal-detector sensitivity. However, once the scale is marked for any one kind of crystal, crystals of that kind should always be used. Other kinds of crystals will give different scale distributions even though the change in over-all range is small. Small variations in sensitivity may be compensated by increasing the power applied from the oscillator to the input to the bridge.

This type of bridge, because of its novel features, has already found application in the solving of many high-frequency problems in other fields. Since it is highly stable, the resistance range of the bridge may be varied widely by choice of the resistance of the bridge arms. For example, with the bridge arms reduced to ten per cent of the original value, the range of the instrument scale will become approximately 20 ohms full-scale; with one per cent of former values, the range can be 2 ohms full-scale; etc. Multirange devices using this principle have been considered. However, as the bridge impedance is reduced, the input power must be increased to obtain the necessary d-c output from the crystal detector. This will require proportionately higher power oscillator supply to furnish the required current to the regulating resistor R_1 to maintain the correct r-f input voltage.

Component Arrangement

In Fig. 3 is shown a top view of a development sample of the meter without its case. At the left is the oscillator, which functions over the range from 50 kilocycles to 85 megacycles. In the center is the semi-regulated power supply; on the right is the bridge block and calibrated variable air capacitor C_s , mounted in back of the bridge block.

Fig. 4 shows the meter assembled in its case. The two controls located at the lower left establish the

frequency at which the meter operates. One is the tuning control and the other the band-change control. The band-change control automatically unmasks the correct scale and adds greatly to the ease of reading the frequency setting.

The knob under the indicating instrument is the zero setting input-power control. To the right of this is the power switch, and directly above the power switch is the calibrated capacitor, which has a range of 20 to 480 μmf . The zero-setting push button is located at the top just above the terminals of the bridge.

Operation

The r-f resistance range is from 0 to 200 ohms. For measurement of pure resistance, the unknown may be connected directly across terminals *A* and *D* (Fig. 1), or for effective resistance of a coil, the unknown is connected to terminals *C* and *D*. Independent circuits consisting of a coil and capacitor may be connected externally across terminals *A* and *D*, in which case the circuit must be tuned to present only a pure resistance across these terminals, which are connected directly to the bridge arm R_5 .

The tube complement consists of a Type 6C4 oscillator, a Type 5W4 rectifier, and two Type OD3/VR150 voltage regulators. The crystal detector is a IN23B, or equal.

Specific accuracies for frequency are ± 1 per cent to 50 megacycles and ± 3 per cent from 50 to 85 megacycles;

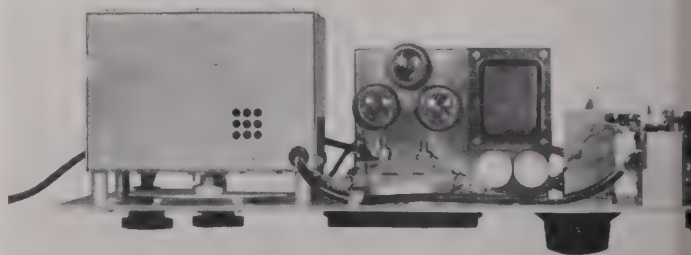


Fig. 3. Radio-frequency meter with case removed



Fig. 4. The new meter is a compact integral unit that does not require the abilities of highly specialized personnel for its operation

± 1 per cent or $\pm 1 \mu\mu\text{f}$, whichever is larger, for capacitance; and ± 5 per cent for r-f resistance.

Some typical measurements that can be made with the new meter will be outlined in the following. Where operating equations are given, the derivation of these equations has been omitted to prevent undue extension of this article. For convenience, the measurement method will be outlined according to three main classes as follows:

- (1). *Class 1.* Measurements that can be made directly across the bridge arm R_5 —that is, between terminals A and D .
- (2). *Class 2.* Measurements that can be made using a tuned circuit comprising an unknown coil connected between terminals C and D and the internal standard capacitor C_s .
- (3). *Class 3.* Measurements that can be made using the device simply as a bridge for an external circuit composed of, for example, primary standard components.

Class I

Resistors

Radio-frequency resistance to 200 ohms can be measured directly by connecting components under test across terminals A and D . The correct value of resistance is the instrument reading. Curves can be obtained showing the frequency at which the resistance starts to change due to inherent inductance or capacitance of the resistor.

Antenna Resistance

Within the limits of direct reading, terminals A and D can be connected at points in antenna systems, where ammeters are normally located, for determining the resonant antenna resistance at these points, thus facilitating the computation of power. For example, center resistance of dipoles can be measured. Base resistance of many antenna configurations can be found, as also can resonant frequencies and resistance at these frequencies.

Class II

Coils

The effective resistance of a coil can be obtained by connecting it to terminals C and D . The reactance of the coil is balanced by tuning C_s (Fig. 1) to resonance. Resonance is indicated by the lowest resistance reading obtainable and is accomplished by tuning C_s , which is calibrated in $\mu\mu\text{f}$. Since the reactance of the circuit comprising the coil being tested is tuned out by C_s , only the effective resistance of the circuit thus formed is across R_5 ; hence, the instrument reads this value directly.

From the values of R , f , and C thus noted, nearly all characteristics of the coil can be obtained. With units in ohms, megacycles, and $\mu\mu\text{f}$, the following equations are used:

Resistance: $R = \text{Instrument Reading}$

$$\begin{aligned} \text{Reactance: } X &= \frac{159000}{fC} && \text{ohms} \\ \text{Inductance: } L &= \left(\frac{25300}{f^2 C} \right) - 0.025 && \text{microhenrys} \\ \text{Power Factor: } PF &= \frac{CfR}{159000} && \text{decimal} \\ Q &= \frac{159000}{CfR} \end{aligned}$$

$$\text{Tuned Parallel Impedance: } Z = \frac{25300 \times 10^6}{RC^2 f^2} \quad \text{ohms}$$

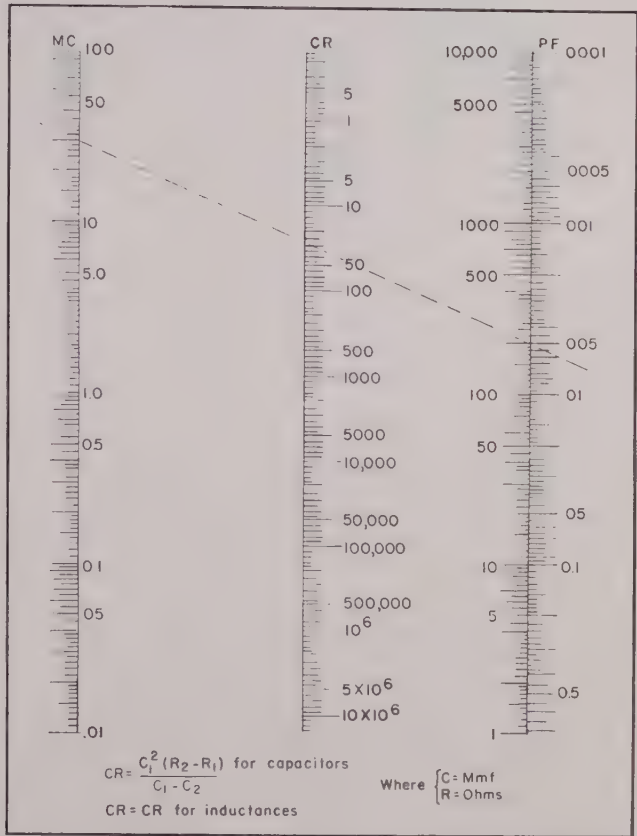


Fig. 5. Nomograph used in conjunction with the meter for quick calculation. For operation at 30 mc with a desired Q of 200, the CR combination of 27.5 is read on the center scale

For measurement of distributed capacity, the coil under test is first resonated to a frequency f_1 , and C_1 is noted. The coil is then resonated to a higher frequency f_2 , and C_2 is noted. The higher frequency can be twice the lower frequency, thus making the denominator of the first factor in the following equation 0.75 and thereby simplifying the operation:

$$\text{Distributed capacity } C_d = \left(\frac{C_1 - C_2}{1 - \frac{f_1^2}{f_2^2}} \right) - C_1 \quad \mu\mu\text{f}$$

A nomograph, shown in Fig. 5, is furnished with the instrument and consists of a frequency scale on the left, a center scale of CR values, and scale of Q or power factor on the right. Both the latter values may

be obtained, if wanted, simultaneously. It is only necessary to multiply the value of C indicated by C_s at resonance by the ohms indicated on the instrument scale. By placing a straight edge through the parameters involved, either or both Q or power factor can be quickly obtained.

For transmitter work, it is advantageous to have coil resistances directly for purposes of power-loss estimations.

Small Capacitors

The characteristics of small capacitors are obtained by connecting them between terminals A and B , thus placing them in parallel with the standard capacitor C_s . A test coil is first connected between terminals C and D , and C_s is tuned to resonance at the frequency of measurement, both with and without the sample. Frequency, capacitances, and resistances are recorded in megacycles, $\mu\mu f$, and ohms, respectively. The following parameters may then be obtained:

$$\text{Capacitance: } C = C_1 - C_2 \quad \mu\mu f$$

$$\text{Effective Resistance: } R = \left(\frac{C_1}{C_1 - C_2} \right)^2 (R_2 - R_1) \quad \text{ohms}$$

$$\text{Reactance: } X = \frac{159000}{f(C_1 - C_2)} \quad \text{ohms}$$

$$\text{Power Factor: } PF = \frac{f C_1^2 (R_2 - R_1)}{159000(C_1 - C_2)} \quad \text{decimal}$$

$$\text{Tuned Parallel Impedance: } Z = \frac{25300 \times 10^6}{C_1^2 f^2 (R_2 - R_1)} \quad \text{ohms}$$

where C_1 and R_1 are values obtained without the sample connected.

Dielectric Samples

The same method of testing and the same equations as used for small capacitors apply to the measurement of the characteristics of dielectric samples. In addition, the following equation is required to determine the dielectric constant K_d :

$$K_d = \frac{4.45 T (C_1 - C_2)}{S}$$

where T = dielectric thickness in inches
and S = active area of dielectric in square inches.

Large Capacitors

Large capacitors are measured by connecting them in series with a test coil and then connecting the combination between terminal C and terminal D . A shorting bar is connected across the capacitor. Values of C and R at resonance are obtained both with and without the sample capacitor short-circuited by tuning C_s . From the values of f , C , and R thus obtained, the capacitor characteristics may be determined as follows:

$$\text{Capacitance: } C = \frac{C_1 C_2}{(C_2 - C_1)} \quad \mu\mu f$$

$$\text{Resistance: } R = R_2 - R_1 \quad \text{ohms}$$

$$\text{Reactance: } X = \frac{159000 (C_2 - C_1)}{f C_1 C_2} \quad \text{ohms}$$

$$\text{Power Factor: } PF = \frac{C_1 C_2 f (R_2 - R_1)}{159000 (C_2 - C_1)} \quad \text{decimal}$$

Effective Series Inductance

$$(\text{When } C_1 \text{ is higher than } C_2): L = \frac{25300 (C_1 - C_2)}{C_1 C_2 f^2} \quad \mu h$$

where R_1 and C_1 are value obtained with the capacitor short-circuited.

Resistors

An alternative method of measuring resistors may be employed wherein the inductive reactance of a resistor is tuned out. The resistor is connected between terminal D and the test coil from terminal C . A shorting bar is used to short-circuit the resistor. The test circuit is resonated both with and without the short-circuiting bar. From the values of f , C , and R thus obtained, the following characteristics of the resistor may be obtained:

$$\text{Resistance: } R = R_2 - R_1 \quad \text{ohms}$$

$$\text{Inductance: } L = \frac{25300 (C_1 - C_2)}{C_1 C_2 f^2} \quad \mu h$$

Series Capacitance

$$(\text{Where } C_2 \text{ is greater than } C_1): C = \frac{C_1 C_2}{C_2 - C_1} \quad \mu\mu f$$

$$\text{Series Reactance: } X = \frac{159000 (C_1 - C_2)}{C_1 C_2 f} \quad \text{ohms}$$

$$\text{Power Factor } PF = \frac{C_1 C_2 f (R_2 - R_1)}{159000 (C_1 - C_2)} \quad \text{decimal}$$

where C_1 and R_1 are values obtained with the resistor short-circuited.

The calibration of the instrument may be checked at higher frequencies quite accurately by substituting a standard decade resistance box in place of a resistor. For each increment of resistance added, the inductance of the box can be tuned out. The method checks the original calibration of the instrument scale.

Large Resistors and Impedances

A coil is connected between terminals C and D , allowing resonance at the desired frequency with tuning of C_s . The resistors or impedances are inserted across terminals A and B , thus connecting them in parallel with C_s . The circuit is resonated both with and without the sample connected. Values of f , C_1 , C_2 , R_1 , and R_2 are obtained respectively. With units in megacycles, $\mu\mu f$, and ohms, the following characteristics may be estimated:

$$\text{Resistance: } R = \frac{25300 \times 10^6}{f^2 C_1 (C_2 R_2 - C_1 R_1)} \quad \text{ohms}$$

Effective parallel capacitance
(When C_1 is larger than C_2): $C = C_1 - C_2$ $\mu\mu\text{f}$

Effective parallel inductance
(When C_2 is larger than C_1): $L = \frac{25300}{f^2 (C_2 - C_1)}$ μh

Effective parallel reactance: $X = \frac{159000}{f (C_2 - C_1)}$ ohms

Power Factor: $PF = \frac{f C_1 (C_2 R_2 - C_1 R_1)}{159000 (C_2 - C_1)}$ decimal

where C_1 and R_1 are values obtained without the sample connected.

R-f Transmission Lines

The surge impedance of transmission lines may be obtained as follows: A short sample of line about one foot in length is required. The sample capacitance is first measured at low frequency, or at some frequency where inductive reactance of the sample is negligible. The remote end of the sample is, of course, open-circuited for this check. The test is similar to that for measurement of capacitors previously described.

$$\text{Capacitance: } C = C_1 - C_2 \quad \mu\mu\text{f}$$

At 100 kilocycles or less this value is very close to the true capacitance of the sample.

The procedure for obtaining the true inductance of the sample is a little more involved, and measurements must be made at high frequencies where insertion of the line sample in series with the test-circuit inductance causes reasonable spread of values of C_s .

The line sample has its remote ends short-circuited. One conductor of the measurement end of the sample is connected to the low, or D , terminal. The other conductor of the cable is connected to the test coil used. A set of measurements is made with the cable input shorted and another with the input free. The distributed capacitance of the coil alone is obtained and also with the coil and line sample as connected in series. These are obtained as follows:

Step 1. Distributed capacitance of coil only with line sample short-circuited.

$$C_{d1} = \left(\frac{C_1 - C_2}{1 - f_1^2} \right) - C_1 \quad \mu\mu\text{f}$$

Step 2. Distributed capacitance of the test coil with the line in series.

$$C_{d2} = \left(\frac{C_1 - C_2}{1 - f_1^2} \right) - C_1 \quad \mu\mu\text{f}$$

In both of these equations, C_1 is resonant capacitance at f_1 , and C_2 at f_2 . Again, if f_2 is twice f_1 the denominator in the first factor can be made 0.75. Both C_{d1} and C_{d2} are usually of negligible magnitudes, but it is advisable to determine whether this is true.

Step 3. The true inductance with the line sample short-circuited is:

$$L_1 = \frac{25300}{f^2 (C_1 + C_{d1})} \quad \mu\text{h}$$

Only the coefficients used in *Step 1* must be used in this equation. The reason for this is that values of C_1 for *Step 1* are different from those of *Step 2*.

Step 4. The true inductance of the circuit with the line sample inductance inserted is:

$$L_2 = \frac{25300}{f^2 (C_1 + C_{d2})} \quad \mu\text{h}$$

Only coefficients in *Step 2* are used.

Step 5. The true inductance of the sample of transmission line is then obtained:

$$L_s = L_2 - L_1 \quad \mu\text{h}$$

Step 6. The surge impedance is then computed by employing L_s and C_s obtained previously:

$$Z_s = 10^3 \sqrt{\frac{L_s}{C_s}} \quad \text{ohms}$$

where L is in microhenrys

and C is in micromicrofarads

True inductance of a short section of transmission line has been difficult to obtain. The new meter makes this possible in a practical way. It is not advisable to attempt to measure attenuation on so short a sample because resistance increments are too small.

Transmission-line Terminations

When the surge impedance of a line of any length is known, it is possible to tell when the line has been properly terminated by connecting the line input with one conductor to terminal A and the other conductor to terminal D . When the meter has been zero-set, the input impedance Z will be read directly as indicated on the instrument. If the line is properly terminated, the meter will read a value in ohms equivalent to the surge impedance of the line, since the line input will appear as a pure resistance. This resistance indication will be constant with frequency. If the line is not terminated

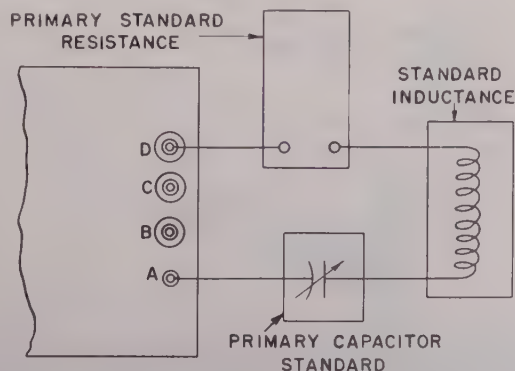


Fig. 6. Assembly of primary standards to obtain high order of precision

(Continued on next page)

ILSCO
LUGS AND
CONNECTORS

It's a Fact!
ILSCO LUGS
ARE
**10% to 20%
COOLER**
than the heavy cast
lugs you now use.



Prove it to yourself—

**WRITE FOR SAMPLES and
the IlSCO 54-page illustrated catalog.**

ILSCO COPPER TUBE
& PRODUCTS, Inc.
CINCINNATI, OHIO

ELECTRITE

A high grade fibre board for electrical insulation. A material of quality possessing high tensile and dielectric strength. Used by many of the leading manufacturers of electrical equipment.

DENSITE

An extremely hard board of superior quality which can replace the more expensive types of insulating materials.

Pulp Products Department

WEST VIRGINIA PULP & PAPER COMPANY

220 Park Avenue, New York, N.Y. 35 E. Wacker Drive, Chicago, Ill.

RESISTANCE METER (Continued from preceding page)

correctly, the indication will be other than the surge impedance and will vary considerably with frequency.

Class III

Measurements with Primary Standards

Where a high order of precision is desired, primary standard components can be assembled exterior to the meter, as indicated in Fig. 6.

Procedure of this kind is generally limited to lower frequencies, since even short leads introduce too much unknown reactance at high frequency. Resistor boxes have inductance, which in some cases, can be tuned out; but many capacitors intended for high-frequency operation have self-resonant periods well within the anticipated frequency bands of operation.

However, by taking account of stray effects, it is possible to check the meter for resistance calibration and to use the bridge for checking or comparing primary standard components of resistance, inductance, or capacitance.

Although there are other uses for which the meter is adaptable, the major ones have been described. And in all its applications, the radio-frequency resistance meter remains a compact integral unit that does not require the abilities of highly specialized personnel to operate, as would any collection of laboratory equipment which otherwise might be used for the same purpose.

Your Own Copy

ON picking up a magazine, nothing is more disturbing than to find that an important article has been clipped out.

Because of the permanently useful information in the REVIEW, many of its articles are clipped out so that this material can be conveniently available for whatever the purpose may be.

In order that you may have your own copy of the REVIEW, complete and without delay each month, we suggest you subscribe now!

GENERAL ELECTRIC REVIEW

SCHENECTADY 5, N. Y., U.S.A.

SUBSCRIPTION RATES: One Year, \$3.50
Two Years, \$5.50

Extra Postage (1 or 2 yr.)—Canada, 25¢; Foreign, 50¢

TRENDS IN AIR CONDITIONING AND REFRIGERATION . . . Part I

A subject of concern not only to the engineers and architects directly involved but also to the electric utilities because these trends will promote more extensive use of electricity and hence will mean increase in consumer loads

By W. E. JOHNSON
Air Conditioning Department
General Electric Company



W. E. Johnson

TO "condition air," or, if you will, "to create a more desirable atmosphere," is a process of the highest complexity and also of the most fascinating human interest.

Each cubic inch of air around us includes some 400 million trillion rapidly moving molecules. At atmospheric pressure, with all this crowding, each molecule moves only about four millionths of an inch before striking another one. The air pressure that we feel is the result of such molecular collisions with all exposed surfaces. Among the many trillions of molecules, of oxygen, nitrogen, water vapor, and carbon dioxide that we think of as air, there are always mixed in vast numbers of other molecules—of argon, helium, sulphur dioxide, ammonia, microbes, smoke, just plain dust, and all those mysterious particles that our noses report to us. Who has not looked with wonder on the quantities of dust floating lightly in the air, that are revealed by a ray of sunlight entering the living room window?

To create the atmosphere we want, the air molecules must be slowed down or speeded up in their motions, thus making us cooler or warmer as desired. Also, the unwanted particles must be sifted, to remove those our noses or our allergies object to; and the number of water-vapor molecules must be nicely regulated. A little thought will suggest that these operations give rise to many problems of high scientific interest, whose economic solutions challenge the best abilities of engineers. Each step in the process is so closely related to others that we need to think of air-conditioning

systems rather than of independent heaters, coolers, humidifiers, filters, and so on. That this is the needed mode of thought has been confirmed by years of development work which have shown how broad a range of activities is necessary to provide the complete air-conditioning systems that are required for comfortable living.

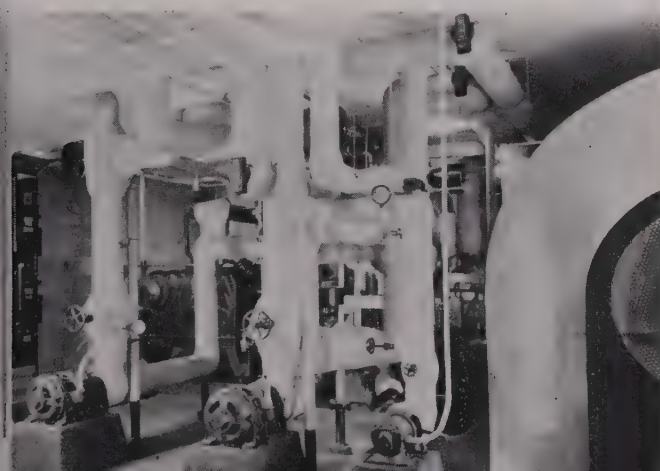
Experience since the war has revealed still more extensive problems, in chemistry as well as physics, that must be solved before the goal of a low-cost all-weather fully reliable home air-conditioning system is reached.

The purposes of this article are to show the nature of some of these problems and to indicate the lines of most likely progress in the air-conditioning and refrigeration fields. In this way, research workers, manufacturers, home planners, and home users may all be enabled to work more effectively toward the common objectives.

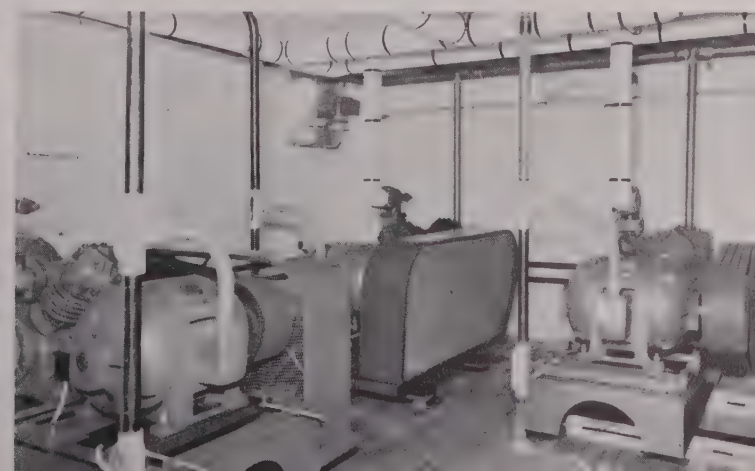
A home air-conditioning system must obviously be designed to fit the house for which it is intended. It is perhaps not so obvious, but fully as important, that the house be designed to fit the air-conditioning system. Unless the two are harmonious, higher costs, less satisfactory performance, and inconveniences in living must be accepted. If architects and air-conditioning engineers understand each other's problems, and work in harmony, we may look forward to delightful comfort at moderate cost in the homes of the future.

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 35 to 40.—Ed.

Machinery room containing reverse-cycle heating and cooling system for an office building. Shown in the background are two 25-hp compressors. The installation also includes central plant conditioners and auxiliary equipment



Three 30-hp motor-compressor units used in conjunction with an evaporative condenser. This air-conditioning system is used in the plant of a fruit company



Functions Performed

In preparation for a consideration of basic problems and trends, a few brief statements of the various functions performed by air-conditioning and refrigeration equipment are given in the following:

Addition or Removal of Heat. This includes electric resistance heating, the pumping of heat by refrigeration machines, and the direct chemical generation of heat through combustion. Usually, but not always, air is the medium through which heat is transferred.

Addition or Removal of Water Vapor. The control of water vapor is one of the more important aspects of comfort air conditioning because of its profound physiological and psychological effects on human beings.

Removal or Inactivation of Impurities. The impurities in room air include gases (such as carbon dioxide, sulphur dioxide, and miscellaneous odors), dust, lint, pollen, bacteria, and chemicals. We still have so much to learn about these unwanted particles that the air-conditioning industry is only in the very crude initial stages of exercising control over them.

Air Movement and Ventilation. In heating and air conditioning, air is often used as the medium for transferring heat. Air-moving equipment is usually a major component of cost in air-conditioning and heating projects.

Balancing Different Kinds of Heat. A sense of well-being requires an appropriate balance among the different means of dissipating heat from the human body. A correct balance of radiation, convection, and evaporation is difficult to achieve but is an important goal of air conditioning.

Preventing Corrosion and Deterioration. Air is often conditioned to prevent the corrosion or deterioration of stored goods. Depending on the nature of these goods, different conditions of humidity and temperature may be desired.

Manipulation of Heat. This was briefly mentioned under the heading of "Addition or Removal of Heat." Manipulation of heat includes pumping heat from one temperature to another (refrigeration), its transfer from one medium to another, and its distribution by a carrying medium.

The object of manipulating heat depends entirely on the application and may range from comfort air conditioning to the conservation of energy in industrial processes.

Refrigeration for Food Processing, Storage, and Transport. The fields of air conditioning and refrigeration overlap to a great extent. For example, in the warehousing of frozen foods, the required low temperature is usually secured by air conditioning. In small food containers for display or storage purposes, the freezing temperatures are often maintained by conduction.

Manufacture of Ice. The manufacture of ice is a large industry and represents an important function of refrigeration. Railroad cars alone use a tremendous amount of ice, and it is required in large quantities for hotels and drinking fountains.

The Control Function. Controls are essential if the other functions mentioned are to be obtained. Humidity, air temperature, radiation, and air movement must all be "sensed" and maintained at the desired levels by automatic controls.

FUNDAMENTAL PROBLEMS

The progress in equipment design can often be sensed for years in advance if the fundamental problems associated with the products are understood. A few of these fundamental problems are now considered.

Combustion of Oil

Over the past several years there has been a strong movement toward the use of automatic heating equipment in the home. Oil combustion presents a fundamental problem in this application.

The actual steps in the oil-burning process are not known with any degree of precision, except for simpler compounds. It is hoped that further research will lead to a better understanding of the reason for flame pulsation with its resulting noise. It seems probable that oil flames can produce types of combustion that are not self-sustaining and which bring about a different reaction which again is not self-sustaining and reverts to the original reaction. There is no confirmation of this theory to the author's knowledge, but it seems plausible. In any case it is evident that a great deal more knowledge of the combustion processes is needed.

Historically, three different theories of combustion have been advanced. First came the theory that the hydrogen of a hydrocarbon burns in preference to or before the carbon. Next came the theory that the carbon burned in preference to the hydrogen. Later, through the experiments of Bone and his collaborators (carried out through the years 1902 to 1906), the hydroxylation theory was proposed and was given additional proof by the work of Wheeler and Blair (published in 1922 and 1923). More recently, added proof of this general theory has been obtained through spectroscopic analysis of flames.

By this theory the complex hydrocarbons of a fuel oil are oxidized during the combustion process to form intermediate hydrocarbon compounds—often alcohols and aldehydes. These compounds in turn may break down into intermediate combustible gases, such as carbon monoxide and hydrogen, or they may burn completely to form carbon dioxide and water vapor.

A number of investigators have tried to improve oil combustion by mechanical control of particle size, mixing, flame patterns, etc. Fairly accurately controlled particle sizes have been made possible by recent advances in the art of producing aerosols. In some cases the particles have been so fine that a dry spray has been

produced, particles of which exhibit the Brownian movement. However, there is no proof that these very fine particles will support combustion.

Another problem in the burning of oil is that of successfully burning catalytic oils in vaporizing burners. The catalytic fuels have a greater tendency toward cracking and polymerization. Again, a fundamental approach to the problem through research is needed

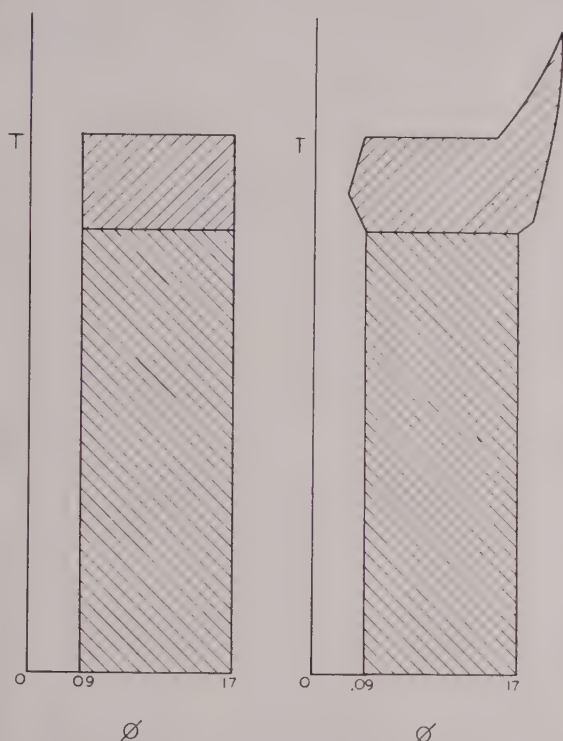


Fig. 1. Temperature-entropy diagrams of the Carnot cycle and a vapor-compression cycle

before the goal of quiet, efficient, and fully reliable burners can be reached.

Combustion of Gas

Technically, the burning of gas poses much simpler problems than the burning of oil, chiefly because the hydrocarbons involved are much simpler, so that the combustion process is more direct. One of the requirements of a gas burner is that it work satisfactorily with a wide range of fuels. The heat content of gases varies over a range greater than two to one. Consequently, the primary air aspirator must be designed to handle a wide range of air-to-fuel ratios.

One problem in the burning of gas is that of suppressing the noise of extinction when the burner is turned off. Other problems concern safety under down-draft conditions and safety of the ignition system.

Most of these factors in the burning of gas are well understood and are under reasonable control in present-day equipment.

Combustion of Coal

The principal effort in the mechanization of coal-burning equipment has, until recently, been directed

toward the development of the mechanical stoker. From the standpoint of providing completely automatic heat, mechanical stokers have not been completely successful, although a number of satisfactory models are on the market.

Recently, attention has again been directed toward the burning of powdered coal, and this process has been looked upon with renewed interest as a result of research work being undertaken in the field of coal-burning gas turbines. A small automatic unit for burning pulverized coal in the home has been developed, but is not on the market at the present time. An automatic unit for burning anthracite has been available for some time. Despite these developments, the national trend has been toward the use of oil-fired and gas-fired equipment, although this trend may be altered by military needs for liquid fuels.

The Pumping of Heat

The pumping of heat is possible because the work energy added to a gas when compressed increases its temperature. Likewise, the work energy taken out of the gas during an expansion makes it cold. If heat is added to a gas before being compressed, that quantity of heat is, in effect, "pumped" to the higher temperature and it may be utilized as desired. In vapor-compression systems the heat is usually added as latent heat, thus adding to the quantity of heat being pumped without affecting the temperature of the refrigerant. This principle can be used in either heating or cooling.

Carnot's work in 1824 defined a limiting efficiency for thermodynamic engines, which we usually call the Carnot efficiency. In a refrigerating machine the cycle is reversed from that of an engine, and we use the inverse of the Carnot efficiency as a "coefficient of performance." If the refrigerating machine is used to deliver heat, this Carnot coefficient of performance is:

$$C.O.P. = \frac{T_1}{T_1 - T_2},$$

where T_1 is the higher absolute temperature and T_2 the lower. If the machine is used to extract heat (as a typical refrigerator) the Carnot coefficient of performance is:

$$C.O.P. = \frac{T_2}{T_1 - T_2}.$$

For moderate temperature differences the vapor compression cycle has always been attractive because the latent heat of the fluid enters into the cycle in such a way that it makes a reasonable approximation to the Carnot cycle with relatively simple mechanical equipment. This is illustrated in Fig. 1.

The open air cycle is generally unfavorable for small temperature differences because the low heat-carrying capacity of the air makes it difficult to approach the Carnot efficiency with equipment of a practical size and with efficiencies normally obtainable in compressors and turbines. At low temperatures, however, the

air cycle is not at so great a disadvantage, and practical considerations will favor its use for many applications.

The ratios between actual coefficient of performance and Carnot coefficient of performance for a vapor-compression machine and for an air-cycle machine are shown in **Fig. 2**. These results are based on some broad assumptions, the principal one being that of perfect heat exchangers. The results take account of machine efficiencies and show that the air cycle becomes relatively more attractive at low temperatures.

Practical considerations will often favor the air cycle. This is particularly true if the medium to be cooled is air, and if the quantity to be cooled is such that the open air cycle is practical. This is often the case in wind tunnels and in high-altitude (low-pressure) testing.

Perhaps one word of caution is in order concerning the use of compressor efficiencies in an air-cycle refrigerator. It has been common practice to use temperature-rise ratio interchangeably with compressor efficiency. For certain purposes this use of the temperature-rise ratio is acceptable. However, when the compressor is used to feed a turbine, such use of the temperature-rise ratio is inaccurate. In this case the efficiency of the compressor should be defined as the ratio of the *available energy in the air delivered to the turbine* to the *energy required to drive the compressor*.

The air-cycle refrigerator can, of course, be used in the production of liquid air, and its use has been proposed for the cooling of buildings with high ventilation loads. This latter application has been considered in an article on the air-cycle heat pump by T. F. Thomas which was presented to the I.M.E. on March 24, 1947.

Absorption Methods of Pumping Heat

Another method of pumping heat is that in which the absorption principle is used. The most common absorption system is that using ammonia. The thermodynamics of this system were discussed by Lorenz in Germany in 1895, and practical applications were made in the first quarter of the present century.

The fundamental action of an absorption system is the solution of a vapor in the liquid phase of a different substance and the consequent suppression of the vapor pressure of the solute. Solvents and solutes are selected for their characteristics of high vapor suppression, ease of regeneration and distillation, and with some consideration of toxic and corrosive properties. Ammonia and water are still the most commonly used materials, although lithium chloride and lithium bromide have both been used with water for air-conditioning systems.

A great many materials have been investigated, but relatively few have the desired characteristics. The most important characteristic is that of vapor suppression, which determines the maximum temperature head that can be sustained. One of the classical problems of the absorption system has been that of securing automatic continuous operation without the use of

mechanically moving parts in the refrigerant circuit. This problem was solved in a household refrigerator by the ingenious use of partial pressures, and in a year-round conditioner by the use of a thermal pump similar to a coffee percolator. In industrial systems the liquid is mechanically pumped from the low-pressure region to the high-pressure region.

The major research problem for the absorption system centers on the search for an ideal solvent-solute combination. The discovery of new materials with

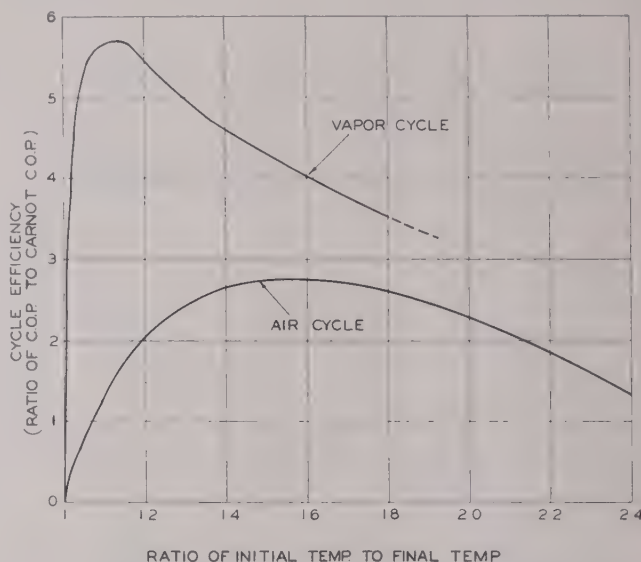


Fig. 2. Ratio of actual coefficient of performance to the Carnot coefficient of performance for the vapor cycle and the air cycle

desirable characteristics might greatly extend the field of usefulness of the absorption system.

Positive-displacement Compressors

The work horse of the air-conditioning and refrigeration industry is the compressor. By far the largest number of installations use positive-displacement compressors of the reciprocating-piston variety.

The great influence on compressor design is exerted, not by mechanical invention, but rather by the characteristics of the refrigerant. Theoretical analysis shows that, with a given ratio of valve port area to piston area, the allowable piston speed for reasonable efficiency is determined by the molecular weight of the gas.

Because of their nontoxic properties, the Freon family of refrigerants is commonly used. This particular group of compounds is characterized by high molecular weight. It can be shown that piston speeds could be increased in inverse proportion to the square root of the molecular weight for the same relative power loss through valves. For example, the molecular weight of Freon 12 is 121, while that of ammonia is 17. Consequently, the piston speed for ammonia with an equivalent valve design could be 2.65 times that of the machine using Freon. Because of power losses due to mechanical friction, it is doubtful whether an actual increase of more than 50 per cent would be used. Nevertheless, it is obvious that this has far more influence on basic compressor design than mechanical refinements, and it points the way to

the need for continued research to discover better refrigerants.

Another major problem in the compressor field is that of chemical stability in hermetically sealed compressors in which the motor is inclosed with the compressor in the refrigerant circuit. Here the problem is one of controlling slow, very complex organic reactions that take place among the refrigerant, oil, metals, and organic materials in the motor insulation. The problem is complicated by various catalytic reactions. The importance of adequate control of the chemistry of these systems can scarcely be overstressed, for the reactions occur very slowly and may cause failure of the system several years after its initial installation.

Nonmechanical Compression

A great deal of thought and inventive ability has been applied in an effort to compress gases without the use of mechanically sliding parts. The long-range objective is a compression system in which no organic materials other than the refrigerant are present, and in which there are no internal parts to become worn.

Up to the present time no one has been successful in producing such a machine, although many diverse methods have been investigated, including the cyclotron and methods of acoustic compression. Some success with the latter has been achieved in Europe in connection with gas-turbine design, but nothing practical has evolved in the field of ordinary compression.

Transfer and Delivery of Heat

The basic problem in the transfer and delivery of heat remains that of performing this function at the lowest cost. The fundamentals are reasonably well established in the range of applications used in air conditioning, and most of the progress in recent years has been due to a better understanding and application of these fundamentals. Fundamental research is still needed on condensation and evaporation coefficients, particularly for systems in which mixed fluids (such as oil and refrigerant) are used. This problem is complicated by the fact that certain refrigerant-and-oil combinations are miscible and others are not.

Air-handling equipment is commonly used for delivering heat, as in the ordinary forced-air furnace. The basic problems are: first, to keep the power requirements within reason; second, to keep within size limitations; and, third, to maintain a satisfactorily low noise level. These problems are all closely associated. Definite progress is needed in terms of better efficiency and lower noise level so that the cost of distributing warm air in a house can be reduced. This is one of the major components of cost in a heating system. Certain kinds of equipment, such as the heat pump, require the delivery of low-grade heat, which in turn requires the movement of large amounts of air with acceptable power and noise. This is a major problem in heat-pump design because the air-handling equipment consumes 25 to 50 per cent as much power as the heat pump itself.

Evidently, extensive work needs to be done in the field of air movement. It is expected that research in this field will benefit from the research previously done for superchargers and gas turbines.

Problems of Cleaning Air

Research on the cleaning of air is one of the fields of investigation which has become increasingly active recently. This field of research holds so much promise for improvement of health conditions, control of allergies, and the general comfort of an invigorating atmosphere, that it is bringing about an increasing degree of interest among scientists and engineers.

The problems are numerous and difficult. The particles to be removed range in size all the way from molecules (odors) to particles thousands of times larger. As always, science must learn to measure before it can make much progress, and one of the first and most difficult tasks is that of measuring what we are doing.

It is reasonably possible now to collect odors, identify them, and weigh the amount collected, thus aiding the problem of measurement in the molecular field. Other researchers are beginning to find out why we smell odors—apparently this sense is related to the effect of infrared radiation on the olfactory nerves. Obviously, more knowledge here will pave the way for cause-and-effect relations.

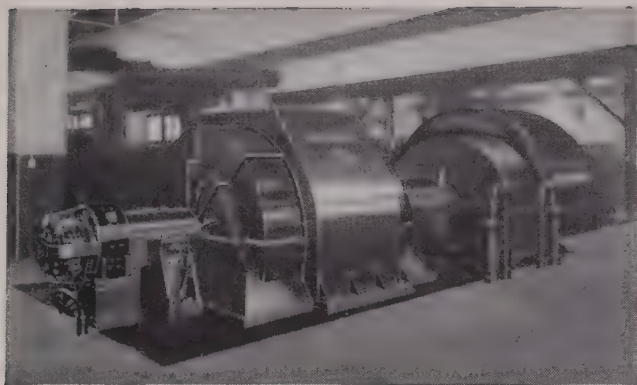
The measurement of larger particles, such as pollens, can be made effectively now by the techniques commonly used by the medical profession, and the same is true (although more difficult) for air-borne bacteria. In at least one case, filtering experiments have proved that a given room can be made practically pollen-free by a simple forced-air filter installation. A much more extensive joint effort of physicians and engineers needs to be made to accumulate a satisfactory weight of clinical evidence, and this is certainly a fruitful field for co-operation between the two professions.

Still another field of measurement needs to be established. This is a definable measure of "dirtiness." One of our objects in cleaning air is to relieve the housewife of some of her distressing dirt problems. Another is to give the occupant freedom from the feeling of grime and dirt on the skin that is so common in dirty atmospheres. Again, some form of measurement is needed before we can talk intelligently about results, or even express what we wish to do. Fortunately, progress has been made on this problem, and we expect soon to know how efficiently we are removing dirt by various filtering methods.

Problems of Control and Measurement

Control problems are usually considered auxiliary to the fundamental problems of the basic apparatus, although very often it is the control that makes the new apparatus possible. A typical case in point is the heat pump, which, while having a number of basic problems itself, really depends upon the development of an integrated control system. There are many other control

(Continued on next page)



9,000 hp Synchronous Motor, manufactured at C-G-E Peterborough Works, driving a centrifugal compressor at a large Canadian nickel mine.

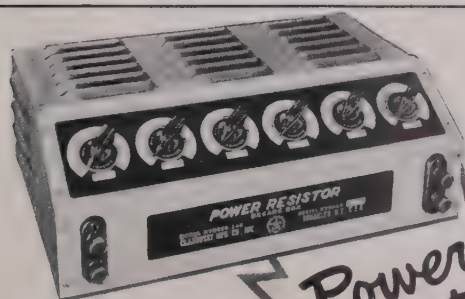
In Canada...

ten factories manufacture General Electric products. 30 engineering and sales offices and 19 warehouses are located from coast-to-coast to serve you.



CANADIAN GENERAL ELECTRIC CO LIMITED

Sydney • Halifax • Saint John • Quebec • Chicoutimi • Trois Rivières • Sherbrooke • Montreal • Ottawa • Toronto • Hamilton • St. Catharines • London • Windsor • Noranda • New Liskeard • Sudbury • Timmins • Fort William • Winnipeg • Brandon • Regina • Saskatoon • Lethbridge • Edmonton • Calgary • Trail • Kelowna • Vancouver • Victoria



Covers resistance range of 1 ohm to 999,999 ohms.

Each decade dissipates up to 225 watts. Greenohms (cement-coated power resistors) throughout. Glass-insulated wiring.

Six decade switches on sloping panel.

Frosted-gray metal case. Etched black-and-aluminum panel.

Grille at bottom; louvers at side. Adequate ventilation.

13" long; 8 1/2" deep; 5 1/4" high. Weight, 11 lbs.

**Power Resistor
DECADE BOX**

★ Here's the Clarostat power resistor decade box. Nothing else like it. You can introduce the correct resistance value in any circuit or for any application, at mere twist of knobs, and then read the resistance value directly off the dials. No calculations. No guess-work. No wasted time. This instrument pays for itself in a hurry. ★ Write for Bulletin 114.



AIR CONDITIONING AND REFRIGERATION

(Continued from preceding page)

problems in air conditioning that are, in themselves, rather fundamental in nature. Some are listed below, together with brief statements of the problems.

Compressor Capacity Modulation. The problem is to vary the displacement rate of a fixed-speed compressor in response to a signal which may be furnished by pressure or temperature. Although this has been done by sequential blocking (in the open position) of intake valves, a more efficient method is desirable.

Compressor Unloading. The problem is to unload the compressor while starting, so that simpler motor-starting equipment may be used on the larger sizes.

Capacity Modulation of Furnaces. It is desirable to provide continuous, rather than on-off heat in houses, and this requires modulation of furnace capacity in proportion to the heat demand.

Measurement of Humidity. Design and test of air conditioning equipment is radically affected by the accuracy of humidity measurement. An error of one degree F in wet-bulb temperatures can readily produce an error of 10 per cent in the size of equipment.

Metering of Refrigerants. A problem as old as mechanical refrigeration is that of metering the refrigerant between the high-pressure and low-pressure sides of the system. Many ingenious controls have been invented, the thermostatic valve, in its several forms, being typical of the art.

The Comfort Thermometer. Thermometers have been proposed which will integrate and measure the effects of convection, radiation, and evaporation in the same manner as a normally healthy person integrates them. Some day this may be done on a commercial scale, together with controlling these separate effects so that the most comfortable conditions are maintained.

There are many other control problems, including those in connection with the cleaning of air, which have already been mentioned. The considerations presented here have been intended only to indicate some of the problems.

(To be continued)

SEXTON CAN COMPANY

Incorporated
Everett Massachusetts

Manufacturers of
Ash Barrels Underground Garbage Receivers
Kitchen Waste Cans

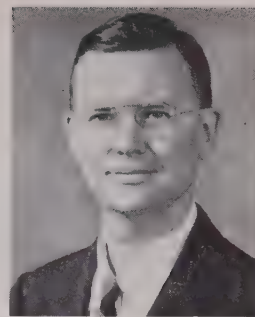
CAPACITOR CASES
both Fabricated and Deep Drawn
FIVE GALLON
Open and Closed Top Shipping Containers

METAL STAMPINGS
SPECIAL SHEET METAL WORK

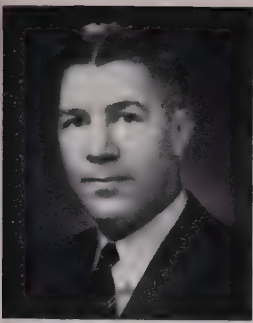
NEW TESTER FOR BALL-BEARING GREASES

Small functional unit has been designed with the reliability and simplicity that permits widespread use among grease manufacturers

By MARSHALL ANDERSON and DR. D. F. WILCOCK
Engineering General Thomson Laboratory
Apparatus Department, General Electric Company



Donald F. Wilcock



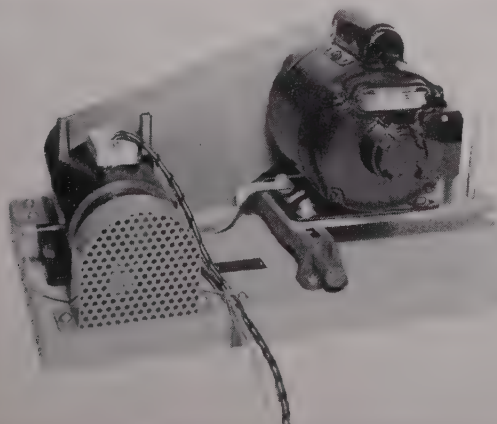
Marshall Anderson

THE physical and chemical characteristics of a grease may be measured in a matter of weeks. This same grease may be expected to lubricate ball and roller bearings for several years. Knowledge of the measured characteristics of the grease, together with the performance records of similar greases, enables the engineer to estimate its performance. However, to know its performance will require years of testing and observation.

In recent years the laboratory engineer has bridged this gap with the functional ball-bearing-grease test machine in which conditions of test similar to those of field use are maintained under careful control. Acceleration of those conditions which are contributory to the destruction of the grease enables a careful, and at the same time rapid, comparison to be made of one grease with another.

A highly simplified version of such a functional ball-bearing-grease test machine has been developed by the General Electric Bearing and Lubricants Center working with the Functional Grease Testing Subcommittee GIII of Committee D-2 of the ASTM. The object was to develop a reliable machine which would also be simple enough and low enough in cost to permit its widespread use among grease manufacturers and consumers. A small number are now being manufactured for co-operative testing among members of the Subcommittee and others. The development unit has been in constant use for over a year.

Fig. 1. The new functional ball-bearing-grease tester, a small, reliable, and highly simplified version



Basic Requirements

In a recent article describing a more complicated grease-testing machine,⁽¹⁾ a number of essential principles were considered:

- (1). The test bearing should be maintained in alignment, preferably by making it one of a pair of bearings located on a common shaft and in an accurately machined housing.
- (2). The test bearing should carry a load simulating the service load.
- (3). The temperature should be maintained constant and at a level above service temperatures to accelerate chemical destruction of the grease.
- (4). The ambient temperature rather than the bearing temperature should be controlled in order not to favor unduly a grease causing a large temperature rise in the bearing.
- (5). The rotative speed, bearing size, and lubrication method should be as similar to the field application as possible.

In the design of the small test machine, some compromise with these principles was inevitable. The principles of alignment, load, and controlled temperature were retained. However, to simplify the design, ambient-temperature control was abandoned, the unit being run in the open and heated internally to maintain a constant bearing temperature. In addition, the bearing size was restricted to the No. 306 deep-groove radial ball bearing, which is a common and typical electric motor size.

Design

The tester is shown in Fig. 1 with the test unit belt driven from an electric motor on an overhung support. The test bearing is at the pulley end of the unit. The radial load on the test bearing is applied through the pulley and belt and may be varied by addition of weights to the motor base.

The details of the construction of the test unit are shown in Fig. 2. The housing is of cast iron, through bored for precision alignment of the bearings. The bearings are free to slide in the housing and carry an axial or thrust load of approximately 40 lb imposed by the wavy spring washer W. The inner races of the

(1) "Life Measurement of Ball Bearing Grease," by Dr. D. F. Wilcock, GENERAL ELECTRIC REVIEW, Oct., 1947, p. 37.

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 41 to 42.—Ed.

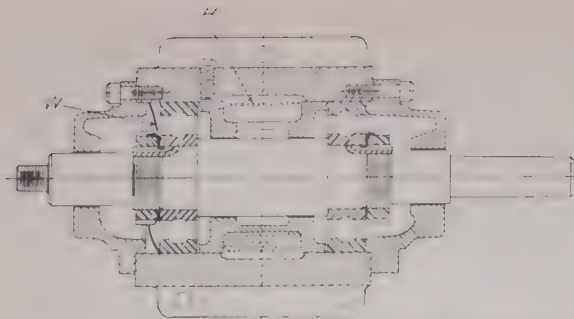


Fig. 2. Cross section of the grease tester showing details of construction

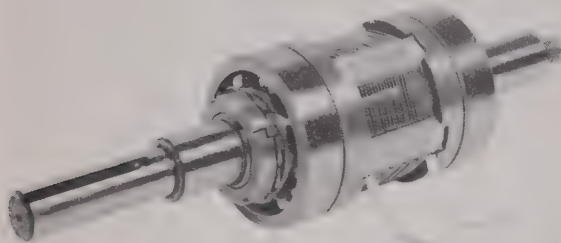


Fig. 3. Heater assembly in position on the shaft

bearings are locked on the ground shaft with standard ball bearing lock nuts. The end caps are usually hand-packed with grease at the beginning of a test. If desired, however, they may be greased through the pressure-gun fittings. For tests of shielded or sealed bearings, the caps may be left empty if desired. For testing the double-row-width type of ball bearing, a longer housing and shaft are required, but other features remain unchanged.

The heater element *H* (Fig. 2) is contained within the unit and thus simulates the source of heat and heat-flow paths in an electric motor. It is an open-wound Nichrome heater radiating to both the shaft and the housing. The heating wire is wound on slotted insulators held by a cast-iron frame. The heater is assembled on the shaft between the test bearing and the guide bearing, as shown in Fig. 3. The entire shaft assembly then may be slid into the housing.

The test shaft is belt-driven at a speed of approximately 3500 rpm. However, both higher and lower speeds are obtainable by simple pulley changes. The development unit has been operated for several hundred hours at 9000 rpm. At speeds much above 3500 rpm it has been necessary to dynamically balance the pulleys to avoid vibration and noise.

Temperature Control

Provision has been made for measuring the outer-race temperatures on the loaded sides of the bearings with copper-Copnic thermocouples embedded in lead tips and pressed against the races by springs. Although the thermocouple on the test bearing could be used with an automatic temperature-control instrument to control the heater, a simpler and less costly method was chosen for this test machine.

Two fixed-temperature mercury-in-glass thermostats are held in wells, one on each side of the test bearing. One of these, T_c (Fig. 4), is selected to close a circuit at the desired operating temperature and controls the heater. The other, T_e , is selected to operate at a higher temperature, usually 10 C above T_c , and shuts off both heater and drive motor should the test bearing overheat, due to lubrication failure, beyond the ability of T_c to control it. A time meter *M* records the total hours of operation.

The control circuit is shown in Fig. 4. Sensitive pilot relays *K2* and *K3* are used between the thermostats and the power relays *K1* and *K4*. The adjustable transformer *V* is set for the desired operating temperature so that the control relay is on about 50 per cent of the time. The control is of the high-low rather than on-off type, since it operates by adding resistance to or removing resistance from the heater circuit.

Operation

Lubrication failure is very often accompanied by a sharp rise in operating temperature of the bearing, which is detected by the thermostat T_e which then shuts the unit off. In other cases, failure is signalled by the bearing jamming, which blows the fuse in the motor circuit. Occasionally, lubrication failure is first noticed from extremely noisy operation.

The speed and load may be varied in the manner already described. The temperature of operation, with appropriate thermostats, may range from just above room temperature to 125 C in conformance with the Committee's recommendations. The development unit has been operated successfully for many hundred hours at 150 C. Since for any testing at temperatures above 110 C it is important to use specially heat-stabilized bearings to avoid dimensional change, bearings used with this tester are stabilized for operation up to 160 C.

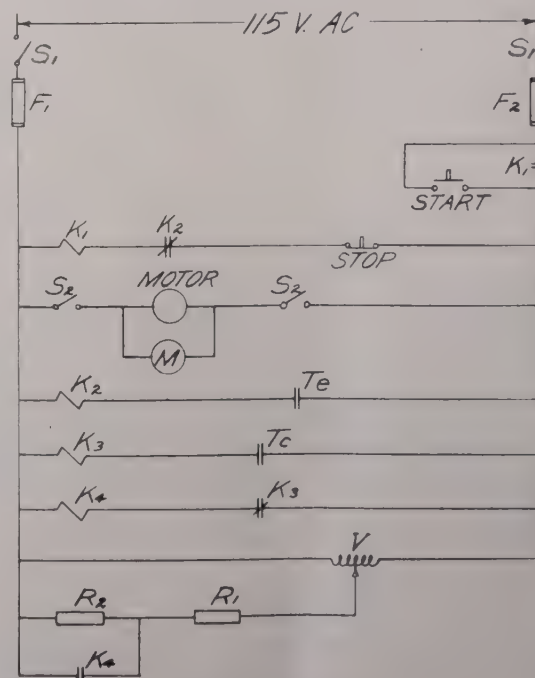


Fig. 4. Control circuit of the tester

ARE NEW TYPES OF TRANSFORMER OIL NEEDED?

. . . Part II . . .

Operating tests being made. The pros and cons of the interfacial test, particularly with respect to deductions respecting performance of oils in service. Inhibited oils and the problems they introduce into commercial operation

By F. M. CLARK

Technical Consultant on Insulation, Apparatus Department
General Electric Company

THE problem of gaging the condition of mineral oil during transformer use presents the most difficult phase of the oxidation problem. The American Society for Testing Materials is now studying this problem. For this purpose, about fifteen transformers have been set up at the Detroit Edison Company, Commonwealth Edison of Chicago, The American Gas and Electric Service Corporation, and Narragansett Power Company. These transformers are working with new and approved oils, with two grades of "poor" quality oil, and with reclaimed oil. The formation of sludge in the transformer, the sludging value tested in accordance with the two ASTM procedures, the color and acidity, and other oil changes are being studied. A better knowledge of the oil problem in service will be obtained as these tests progress. They have been in operation now for about two and one-half years without sufficient change to warrant definite conclusions.

It has generally been the practice for the operator of a transformer to evaluate the condition of an oil on the basis of acidity and color change. From what has already been said with regard to the rate of acid change as a function of the type of crude and the effect of refining, as well as the effect of contamination, it appears that these properties do not provide a reliable basis for the evaluation of transformer oil during commercial use unless consideration is given to its chemical nature and previous history. Since these tests probably err on the safe side, however, they do give a measure of protection to the operator.

Acidity change is of importance because of its relation to tests such as the power-factor and interfacial-tension tests, which are being so strongly advocated at the present time. The difficulty with the acidity test is that the rate of acid formation is strongly affected by the use of different crude-oil types and by the degree of refining treatment. But there is still another factor of importance. In actual transformer use the rate and amount of acid formed is not continuous. Acid formation in transformer oil during use increases more or less rapidly to a maximum value which is dependent upon many factors, one of the more important being the operating temperature. The higher the operating temperature of the transformer, the higher is the maximum acidity value which is reached.

During transformer operation at 60 C, for example, the acid value of the usual American transformer oil appears to stabilize at about 0.65 to 0.75 mg of potassium hydroxide per gram of oil. At 80 C, the stabilized value is about 0.75 to 0.95 mg. This stabilization affects the value of the acidity test as a criterion of oil condition and influences the value of all other tests which are wholly or partially dependent, in their results, upon the continued accumulation of oil acids.

The explanation of acid stabilization is not difficult. Sludge formation is the final step of the oil oxidation; acid formation is an intermediate step. First, peroxides are formed. These are ultimately converted into oil acids. Oil acids are partially removed in the formation of sludge which consists, in part, of metal soaps and, in part, of condensation products due to the interaction of oil acids with themselves or with other oxidation products. A careful study of acid and sludge formation shows that they proceed in steps. The acidity first increases, then is substantially constant while the sludge deposition is increasing. Ultimately, however, an equilibrium appears to be formed during which further increase in acidity is offset by simultaneous removal of acidity as sludge. During this period the oil power factor and other oil characteristics, even including oil color, change but little. The power factor and the ASTM sludge value may actually decrease. Yet oxidation changes and sludge deposition proceed apace. That constitutes the danger and difficulty involved in the practical application of most of the oil tests so far suggested.

Interfacial-tension Test

The interfacial-tension test has most recently been suggested as a gage for determining the condition of mineral oil in transformer use. A molecule located in the interior of the liquid is acted upon by attractive forces from all directions. A particle on the surface of a liquid is attracted inward by the attraction of all the molecular particles of the liquid within its sphere of influence. It follows therefore that there is a force—the so-called surface tension—which acts inward, the liquid behaving as if it were covered by an elastic skin.

Surface Forces

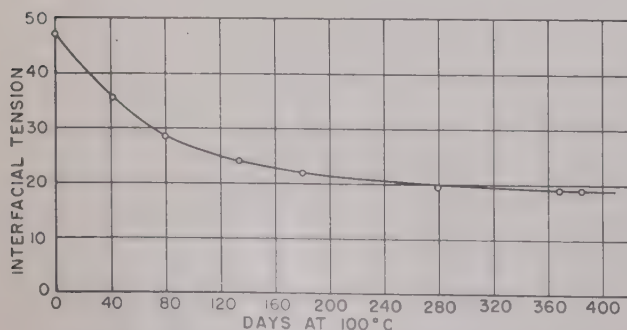
Surface tension is an evaluation of the surface forces acting upon a molecule of a liquid in contact with a gas. When the same liquid is in contact with another liquid,

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 43 to 47.—Ed.

the surface forces may be considerably altered as a result of the molecular rearrangement in the liquid at its interface. In the case of a liquid in contact with water, the surface force exerted by the liquid will be determined by its hydrophilic or hydrophobic nature. Under these conditions pure hydrocarbons, having little affinity for water (hydrophobic in nature), exert a maximum of force on their own surface molecules. Organic acids and alcohols, having greater affinity for water (hydrophilic), exert a lesser force on their own surface molecules. The hydrocarbons, therefore, have high interfacial tension; the acids and alcohols have low interfacial tension. The more highly refined the oil, the greater the hydrocarbon content and the greater this surface force against water will be, with the result that a highly refined oil will pull into a sphere when placed on water. When the oil is oxidized, the formation of hydrophilic materials (organic acids) tends to reduce the tension at the interface between the oil and the water, and the oil spreads over the surface of the water with increasing ease. The force necessary to overcome this spreading tendency is the hydrophile value, which has been so thoroughly studied by Dr. Irving Langmuir.

Test Procedure

The interfacial-tension test measures surface phenomena. In this test, however, the spreading tendency, or interfacial value, is measured as the force necessary to pull a carefully prepared platinum wire through the water-oil interface. This force is expressed in dynes per centimeter. In a commercially refined mineral transformer oil, the interfacial tension as normally measured is about 40 to 50 dynes per centimeter. Academically, the interfacial-tension test could be used to determine the presence of soluble contaminants in the oil. Practically speaking, however, the amount of contamination in new oil is so low that the test is not sufficiently sensitive or discriminatory to be of any

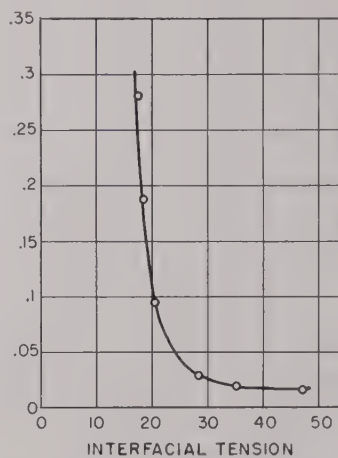


Change in the interfacial-tension value of a typical mineral transformer oil during oxidation at 100°C over a period of approximately one year

commercial value for that purpose. Substantially all commercial transformer oils have about the same interfacial-tension value. It is on the change in interfacial-tension value as the result of oxidation that its advocates have based its claim for utility.

When an oil is oxidized the interfacial-tension value drops asymptotically with time. This change reflects the increased hydrophilic content of the oil and is especially pronounced in the early stages of oxidation. In other words, a small amount of oil oxidation causes a large decrease in interfacial-tension value. Experience in certain utility transformers has indicated that when the interfacial value has been lowered to about 20 or 24, the oil has sludged and should be carefully watched if continued in use. It has also been suggested that an oil with a value as low as about 16 or 18 should be withdrawn from service.

The interfacial-tension value is determined by the presence or absence of hydrophilic materials dissolved in the oil. In that sense it is a more inclusive test than the acidity test. But since the materials most hazardous



Approach of the interfacial-tension property to a stabilized value when the oil becomes more seriously oxidized, as gaged by the acid value

from the dielectric standpoint are water-soluble, or at least hydrophilic, the value of the interfacial-tension test appears to warrant further consideration. However, except for an increase in the power factor of an oil, the presence of these hydrophilic materials is hazardous only in the presence of water. The hazard of water, which is normally great in any oil irrespective of its interfacial value, suggests that in this respect a direct test for water would be preferable to a test for the interfacial-tension value.

The interfacial-tension test has been suggested not merely for evaluating the dielectric hazard, but as a gage for determining the "oxidation condition" of an oil. A marked drop in the interfacial-tension value is claimed to indicate need for oil treatment. But experience has shown that an oil with an acidity of 0.2 does not normally require treatment. Yet a typical American transformer oil with an interfacial-tension value of 20 to 22 usually has an acid value of only about 0.2 mg of potassium hydroxide per gram. For lower values of interfacial tension, the decrease with time of oxidation becomes less. In other words, the interfacial-tension value changes more slowly as the acidity increase becomes more pronounced. This might be considered as a defect in the interfacial-tension test.

Its sensitivity decreases as the critical point in the operation of the transformer is approached. To some extent this decreased sensitivity is offset by the greater accuracy of the interfacial-test values obtained. The test has been found to give easily checkable results.

Evaluation of Test

It is neither surprising nor technically important that it is possible to assign approximate values for the interfacial test to indicate when a selected oil is beginning to sludge or when a substantial amount of sludge is normally present in the grade of oil used in American transformer practice. Many of the oil tests suggested during the past decade can be handled in the same way. For example, when the acidity of the usual transformer oil is about 0.4, sludge is generally beginning to form in the oil. When the oil color is 2*, sludge is usually beginning to deposit in the oil. When the acid value reaches 0.7 or 0.75, or the color 4 or 5, the oil is substantially sludged.

The preceding statements are good generalizations. But like that of the interfacial-tension value, their fundamental importance may be grossly exaggerated since they neglect three important technical factors: the design of the transformer, its temperature of operation, and the nature of the oil used. Such generalizations assume that all transformer oil is of the same type and refined to the same degree as the oil most generally used in this country. In their practical application, those generalizations assume that there is a certain critical amount of sludge which is standard for the operation of all transformers. They also neglect the fact that the temperature of operation determines, to a large extent, the type of oxidation product formed and the hazard in the use of an oxidized oil. These are fundamental considerations which cannot be ignored.

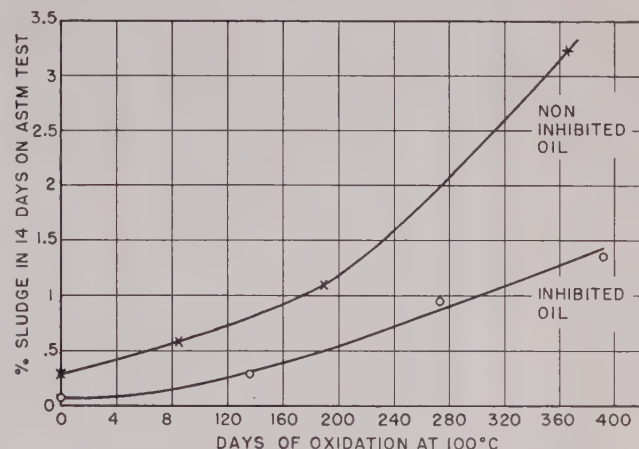
The weakness of the acidity or color-oxidation test in an oil is that its value depends upon a constant correlation between it and the sludge formed. This correlation is not constant but is affected by the temperature, the nature of the oil, and other factors. And like the interfacial-tension value, the acidity and color values appear to stabilize as the oxidation approaches a critical condition.

Inhibited Oils

If sludge is the real problem in oil-filled transformers, why not face the issue and eliminate it entirely? That is a logical question. There are transformers in operation with nonsludging askarel liquids, the use of which eliminates the sludge problem. However, the question is usually put forth with reference to the use of inhibited oils. Why not use inhibited oils and eliminate the sludge problem?

The possibility of using an oxidation inhibitor in mineral transformer oil has been the subject of technical discussions for many years. Numerous patents have been issued covering a variety of inhibitors. The possibility of inhibiting oxidation and sludge formation

has been established. The transformer engineer and operator, however, have been faced with the problem of determining the dielectric hazard, if any, which is presented by the use of the inhibited oils and their economic advantage in terms of longer commercial life and reduced maintenance expense.



Comparative sludging tendencies in a noninhibited and an inhibited transformer oil as revealed by a laboratory demonstration

The use of inhibitors has been of value in many widely varying fields of application. Their use has been credited with increasing manyfold the useful life of rubber tires. In the motor- and turbine-lubricant field, the application of the inhibitor has been of real value. In the use and handling of mineral transformer oil, however, there are numerous peculiarities which warrant a review of the practical problems accompanying the general use of inhibited transformer oils.

Compatibility of Inhibitors

It is recognized by all investigators that an inhibitor which functions satisfactorily in one type of oil may not function satisfactorily either in the same type of oil if refined to a different degree or in a different type of oil if refined to about the same degree. This is important. Suppose one manufacturer makes a good transformer and fills it with a specially selected oil compounded with a specially selected inhibitor which has been found, in both laboratory and semicommercial investigations, to endow the oil with excellent oxidation resistance. The operator of the transformer uses a different type of make-up oil over the years, or for one reason or another, such as for inspection purposes or because of technical troubles, the operator drains some of the original inhibited oil from the transformer and replaces it with an oil purchased from another supplier. Both grades of oil may have been of excellent sludge resistance, each with its own inhibitor; but the operator has neither the time nor the facilities to study the compatibility of numerous types of oils and stabilizers. He may be lucky, for perhaps these particular oils and inhibitors are compatible. But they may not be.

Of course this situation can be corrected. The manufacture of the oil may be restricted to a selected few, or the types of stabilizers used may be restricted, or

*Color standards were illustrated in Part I, in the May, 1948 issue.

the type of oil used and its degree of refining may be carefully delimited. Such a solution of the problem, however, runs point-blank against the fundamental problem of restriction of material supply.

Dielectric Problem

Even though an inhibitor may be satisfactory for chemical reasons, its use may present a dielectric hazard. Many inhibitors which have been suggested in technical and patent literature have poor dielectric properties. Their use may present a dielectric hazard either when new or after oxidation and conversion to other chemical forms.

The solution of this problem demands the use of approved inhibitors, the approval of which has included consideration of dielectric stability of the inhibited oil under the most severe conditions of operation. Since the field of inhibitors has been quite thoroughly covered by patents, this may mean the widespread selection and use of a limited number of patented products.

Inhibited Oils in Circuit Breakers

The inhibited oil has been found to have little if any advantage in switchgear and circuit breakers, where oxidation effects are not pronounced. Research has even shown that certain types of inhibited oils may have a disadvantage in such equipment, since the presence of the inhibitor may greatly affect the particle size, and therefore the rate of carbon settling from the mineral oil, after it has been subjected to electrical arcing such as occurs in normal operation of the apparatus.

Again the problem presented is not insurmountable. There are two possible solutions. The first is the obvious solution of reverting to the former practice of using separate oils for transformers and for circuit breakers. The technical solution of the problem is one of careful selection of the inhibitor. The cumulative effect of all these necessary restrictions may present a most serious problem from the standpoint of the cost and the availability of a suitable transformer oil.

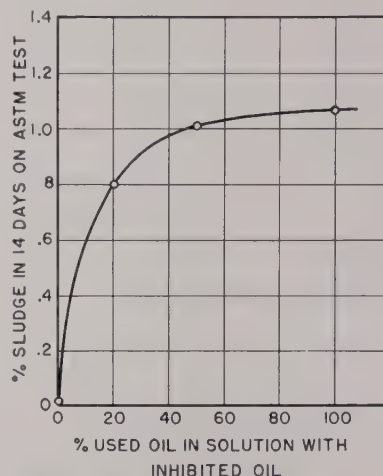
Cost of the Oil

It is recognized that an inhibited mineral oil will cost more than the noninhibited transformer oil now in wide usage. This, however, is not basically a technical problem; it is a commercial and operating problem. If the use of an inhibitor eliminates or sufficiently reduces operator maintenance, the additional cost might be justified. It appears, however, that in normal transformer operation the maintenance problem is as much a dielectric problem as a sludge problem. If so, careful analysis will show whether any important cost reduction in the maintenance of a transformer is possible through the use of inhibited oils. Such analysis should, of course, include consideration of present trends in transformer design, such as the use of sealed transformers with nitrogen gas cushions, the conser-

vator, and other mechanical devices which serve to reduce the oxidation problem.

Problem of "Used" Inhibited Oils

If the use of inhibited oil completely eliminated the sludge problem, that in itself might be sufficient advantage to justify the increased cost and the contingent problems already described. The transformer would then operate indefinitely with clean coils and freedom from sludge. But even the strongest advocates of inhibitors do not claim this. They admit that eventually the inhibitor will be "used up," and that sludging will then occur at a normal, or possibly an accelerated, rate. Since such a condition will not be reached for some time, there is frequently a tendency to dismiss this



Relation of sludging tendency to the percentage of used oil in solution with inhibited oil. Addition of an inhibited oil to a transformer already in commercial use must be made only after the transformer has been carefully cleaned, for the presence of "used" oil may greatly affect the stability of the inhibited oil. Acidity of used oil: 0.63 mg KOH per gram of oil

type of problem. It is one, however, which should be given thorough consideration. To reach a sound technical conclusion as to the merits of the inhibited transformer oil, problems presented in the handling of "used" inhibited oil must be as carefully reviewed as have been the similar problems presented in the handling of the noninhibited oils upon which so much of the argument for the use of oil inhibitors has been based.

In the use of rubber tires, the customer's interest in the tire ends when it is used up. Anything which will extend the time interval of useful service is important. When the tire is worn out, however, it is discarded. Its reclamation value is the problem of the rubber expert.

In the lubricating field, there is a continuous loss of lubricant, and additions of new inhibited oil serve to replenish the inhibitor supply. The careful technical and semitechnical attention given turbine oil during its use serves to prevent any abnormal behavior from assuming hazardous proportions.

With mineral transformer oils, however, these considerations of the tire operator or the turbine applica-

tion do not apply. To realize the advantage of the inhibitor, there would have to be less transformer supervision. Although the useful life of the inhibited oil is not known at present, it is expected that even the most resistant oil eventually will sludge. It is expected, furthermore, that there will be a wide variation in the useful life of different inhibited oils in view of their expected differences in refining treatment and in the efficacy of their individual inhibitors. When sludged, unlike the outworn automobile tire, the oil will not be discarded as useless. Following present practice, it is expected that there will be a demand that the oil be reclaimed. And here we are back at the same old problem, except that we are now dealing with a more expensive material. The old questions arise: When shall use of the oil be discontinued? What tests are of value in ascertaining when the hazard is too great for safety?

These problems are made more difficult in the inhibited-oil application than at present, for the hazard involved depends upon the degree of refinement and the type of base oil. The hazard is greater for the more highly refined inhibited oils than for the present type of American transformer oil because of the rapid accumulation of corrosive acidity once the retarded oil is used up. These inhibited oils, however, may be among the best of the new oils on laboratory tests. But even with oils which are not highly refined the hazard is not easily evaluated, for the oils may be refined to a widely varying degree. The base oil will be refined to the degree best suited to meet the original requirements of the purchaser. This could be either a basic requirement of sludge quality or a basic requirement of minimum cost to meet a sludge standard. The possibility of using a poor grade of oil with a retarder to meet a standard sludge value for the blend will be very strong in view of the cost factor. This, however, will ultimately increase the operational hazard when the retarded oil has been used up. The present problem of evaluating the hazard will only be postponed. It cannot be eliminated by the use of a retarder-treated oil.

Reclamation

And then there is the problem of reclamation. The present methods of reclaiming oil by the use of adsorbents like fuller's earth will probably be continued because of their low cost and simple technology. Such processes, if applied during the useful life of the oil, will remove the inhibitor entirely or in part. This means the development of a test to determine whether enough of the inhibitor remains to be effective. It also means the addition of a new quantity of inhibitor to an oxidized or partially oxidized oil whose compatibility with the inhibitor present may not be known. And if the oil is run to its maximum permissible sludge value, the usual reclamation problem confronts the operator, plus the addition of new inhibitor to insure the proper functioning of the oil. This will present the same technical problem of selection and blending which con-

fronted the oil supplier in furnishing the original oil. The problem is the same except that the oil company is better equipped, by experience and with trained personnel, to obtain a satisfactory solution. The original supplier of the oil also has a complete knowledge of the type of oil used and its refining history, information which is most frequently lacking in the operator's records. Furthermore, some inhibitors will not function satisfactorily in a reclaimed oil. Some inhibitors will not function satisfactorily even if the original inhibited oil is merely blended with a substantial amount of a reclaimed used oil.

The problem of supplying an inhibited oil is simple, and most technologists who have studied the oxidation problem in mineral oil have developed their own special inhibitors. Dissertations could be written and many articles published showing the remarkable chemical stability of a wide variety of inhibited oils. The problem, however, is to evaluate the over-all dielectric and chemical advantages and hazards presented by the use of these oils during years of commercial transformer use. That is a technical problem which cannot be solved in a short time of transformer operation under abnormal temperatures or other operational conditions. The other phase of the problem is one of fundamental economics in operation. Accepting the claims of its advocates as to its qualities, is the use of the inhibited oil economical and sound? What is the oil maintenance cost of the modern transformer? How is the cost affected by the use of the conservator, the sealed tank, gas-oil seal, or nitrogen-pressure transformer design? Will the use of an inhibitor reduce these maintenance costs to the advantage of the operator? Will the postponement of oil reconditioning by the use of inhibited oil offset its initially higher cost? If so, how much "postponement" must be obtained if the initial oil cost is increased 20 per cent? 50 per cent? Will the industry desire to go back to two oils—one for transformer and one for switches? If so, under what conditions?

The use of inhibited transformer oil presents both a technical and an economic problem. Technically, the problems presented are similar to those which have confronted the industry in the use of the noninhibited oils. They differ chiefly in the matter of degree and timing. In some respects, the problems presented by the use of inhibited oils are more difficult and more important in their proper solution than the problems now confronting the industry in the use of the noninhibited oils.

Continued research and engineering development are necessary to form a firm foundation of exact knowledge. With that foundation, improvements in the technique of refining transformer oil and the development of more satisfactory evaluation tests may well be expected to contribute their share toward the realization of the more reliable transformer of the future.

(Concluded)

HOP ON -- AND *Go!*



Free Enterprise places the vehicle of opportunity before the individual and says: Hop on — and go!

The vehicle in this case is every man's right to do as he pleases — so long as he doesn't collide with the rights of others. There are no other barriers in the path of his progress. He can go as far as his talents, determination and resourcefulness will carry him.

Free Enterprise means what it says — freedom to dare, to do, to develop.

There is nobody to say — you may, or that your neighbor may not.

Nobody can dictate your itinerary for you — but you!

It's up to you . . . hop on — and go!

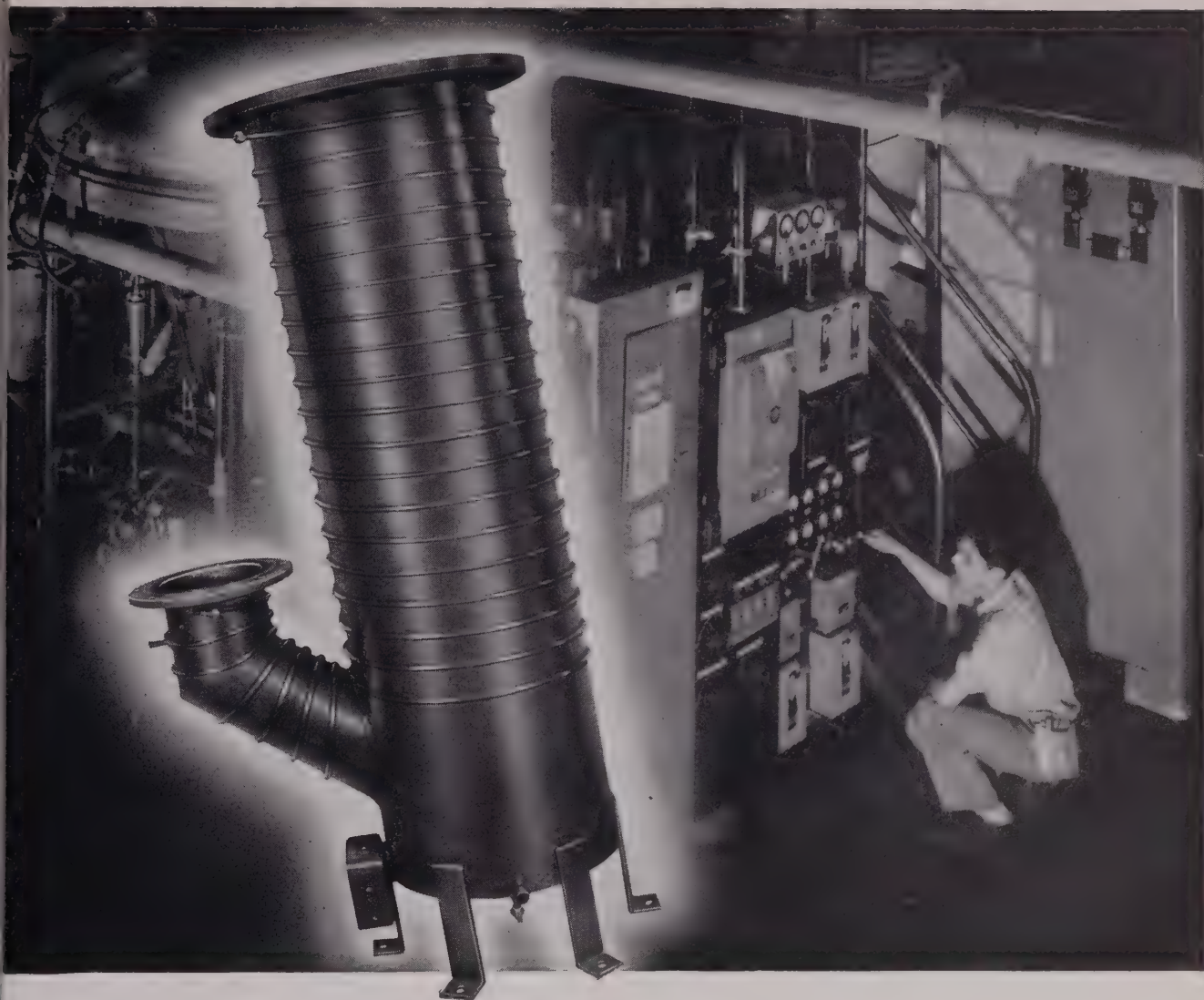


SHERRON ELECTRONICS CO.

Division of Sherron Metallic Corporation

1201 FLUSHING AVENUE • BROOKLYN 6, NEW YORK

MANUFACTURERS OF ELECTRONIC DEVICES AND SHEET METAL FABRICATION



***BIG CAPACITY PUMPS* FOR VACUUM OF ONE-BILLIONTH OF AN ATMOSPHERE**

AMERICAN production is discovering startling ways to use high vacuum. Commercial applications in the broad fields of electronics, metallurgy, physical chemistry and nuclear physics are demanding large capacity pumps and components for fast, large-scale production:

To provide the necessary equipment, DPI's engineering department has developed a wide variety of diffusion pumps of rugged, all-metal construction capable of pumping many thousands of cubic feet per minute without sacrificing low ultimate vacuum achieved by the finest

laboratory apparatus. This line of large-capacity, high-vacuum equipment and the technical knowledge acquired by DPI research men and engineers are available to industries interested in the possibilities of high-vacuum processing—or in improving present high-vacuum installations. Write:

Vacuum Equipment Division

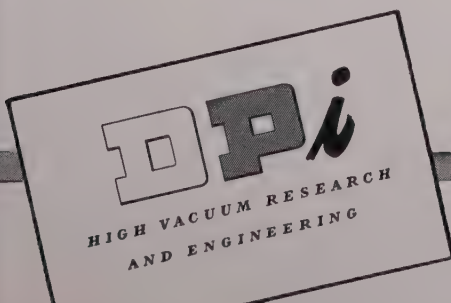
DISTILLATION PRODUCTS, INC.

773 RIDGE ROAD WEST • ROCHESTER 13, N. Y.

570 Lexington Ave.
New York 22, N. Y.

135 So. La Salle St.
Chicago 3, Illinois

Manufacturers of Molecular Still and High-Vacuum Equipment; Distillers of Oil-Soluble Vitamins and other Concentrates for Science and Industry



Electron devices in which secondary-emission phenomenon are utilized. Over-all gains of a millionfold are considered. Control of secondary emission to obtain desired effects

By DR. L. R. KOLLER
Research Laboratory, General Electric Company

ONE of the most successful electronic devices using secondary emission is the secondary-emission multiplier phototube.⁽¹⁵⁾ In this device, secondary emission is used to amplify a small photocurrent approximately one millionfold.

Operating Principles of Secondary-emission Multiplier

The photoelectrons from a photocathode are made to strike an electrode called a dynode, causing the emission of several secondaries for each primary. These secondaries are then accelerated to another dynode, where each causes the emission of additional secondaries. Thus, through a succession of such steps a large amplification is obtained.

In practice nine steps are used, the electrons being accelerated through about 100 volts at each step. This necessitates about 1000 volts for the tube. If the yield is δ , then the total amplification is δ^n , where n is the number of dynodes. The surfaces commonly used as dynodes in electron multipliers give $\delta=4$ or 5 at 100 volts; hence the over-all gain with 1000 volts across the entire system is about one millionfold.

Fig. 13(a) shows a photomultiplier tube, and Fig. 13(b) shows the schematic arrangement. The over-all gain is adjustable within limits by varying the applied voltage which determines the secondary yield. This flexible voltage-gain control is also a disadvantage in that it necessitates a very constant source of supply voltage. Multipliers have been built with both electromagnetic and electrostatic focussing. The latter is now generally used because of compactness of design.

(15) Zworykin and Morton: *Television*, Wiley, 1940.

Fig. 13(a). An 11-electrode vacuum phototube wherein the photocurrent produced at the cathode is multiplied many times by secondary emission, occurring at successive dynodes within the tube. This tube can multiply as much as 200,000 times the feeble currents produced by weak illuminations

Among the advantages of the secondary-emission multiplier, in addition to its high amplification factor, are its compactness, simplicity, and ease of shielding. It is particularly well adapted to the amplification of small signals because of its high signal-to-noise ratio.

In thermionic amplifiers there are two inherent types of noise. One of these is associated with thermionic emission and is due to the randomness of this process. The emission is that of a stream of discrete particles rather than a continuous fluid. This stream is not uniform but slightly fluctuating because the number of electrons emitted in successive time intervals is not the same. This fluctuating emission results in a fluctuating output, and, since these fluctuations occur at audible frequencies, they produce noise in the amplifier output. This is known as "shot effect."

The other type of noise is introduced by thermal agitation of the electrons in the amplifier input or coupling resistor, the result of the random thermal agitation of the electrons in the input circuit. This noise, known as Johnson noise, is usually large compared with the shot effect. These two effects are well understood, and their magnitudes can readily be calculated.

In the phototube multiplier, there is no coupling resistor between stages; hence this source of noise is eliminated. The chief remaining noises are the thermionic emission from the cathode and the noise due to the shot effect of the photoelectric current. The former can be reduced to some extent by cooling the tube. (Noise due to leakage currents, ion currents, and field currents can be kept to a minimum by proper design and exhaust of tubes.)

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 50 to 52.—Ed.

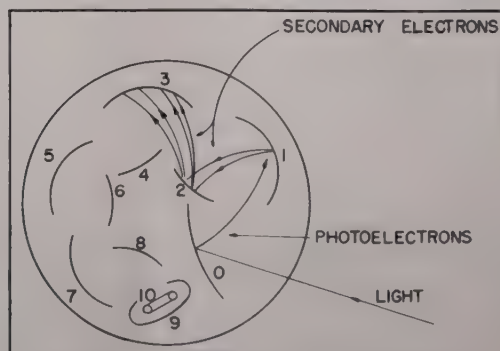


Fig. 13(b). Schematic diagram of photomultiplier tube

0: Photocathode
1 to 9: Dynodes
10: Anode

The secondary-emission process is also a random one. The number of secondary electrons per primary varies from one electron to another, although the average ratio is constant. This introduces additional noise in the output. The magnitude of this effect however is relatively small, about 15 per cent of the noise due to other causes. Signal-to-noise ratios of about 40 db are readily obtained by operating phototube multipliers under the proper conditions.⁽¹⁶⁾

An interesting application of the phototube secondary-emission multiplier is the image tube dissector.⁽¹⁵⁾ In this tube the optical image is focussed on a photoelectric surface. The resultant photoelectric current is then focussed on a collecting electrode at the end of the tube. By means of a magnetic field the electron image is swept line by line across a small opening in this collector so that all parts of the image move across the opening in succession. Behind this opening there is a small photoelectric surface which acts as the first electrode in an electron multiplier and amplifies the small photocurrent. Instead of the process of scanning a fixed image with a moving beam, in this tube the image itself is caused to move over the receiver of the amplifier.

Iconoscope

The operation of television-camera tubes, such as iconoscopes, is greatly dependent on secondary emission.⁽¹⁶⁾ The photoelectric mosaic in these tubes is repeatedly scanned by a high-voltage electron beam. Because the surface is an insulating one, it assumes a potential near anode potential by the mechanism described for the emission of insulators. This potential is modified by the photoelectric effect when an image is focussed on the tube. Differences in potential corresponding to differences in illumination are amplified and transmitted to the receiver and the kinescope. These details, however, are too complex for inclusion in the present article.

Magnetrons

Secondary emission also plays a part in the operation of magnetrons. In these tubes some of the electrons which leave the cathode are turned about in the magnetic field and returned to the cathode. This "back bombardment" of the cathode by thermionic electrons results in additional heating and thermionic emission and, at the same time, in some secondary emission.

Dynatrons

Secondary emission in triodes is usually a disturbing factor in the operation of the tube; but like many other forces, if properly harnessed, it can be put to practical use. The effect of secondary emission on the plate-voltage plate-current characteristic of a triode has been described in Part I of this article. An early practical application of this characteristic was made in 1916 by A. W. Hull, who showed that it could be made to

produce oscillations.⁽¹⁷⁾ Tubes operating on this principle are called dynatrons.

The plate-current plate-voltage characteristic of a dynatron is shown in **Fig. 14**. In the region from V_1 to V_2 , the plate current decreases as the plate voltage increases. Any device such as this in which the current decreases as the voltage increases constitutes a negative resistance. The value of the negative resistance is $\Delta V / \Delta i$. When a parallel resonant circuit with the proper constants is connected in series with the negative resistance, oscillations are produced. Accordingly, the dynatron is a generator of high-frequency oscillations. The frequency is determined by the inductance and

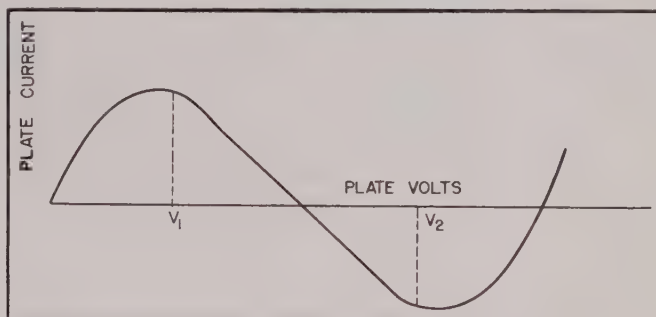


Fig. 14. Dynatron characteristic curve

capacity of the circuit; the amplitude is determined by the length of the straight portion of the curve. The condition for oscillations is that the negative resistance must be slightly less than $\frac{LC}{R}$. This very simple form of

oscillator has not been used to any great extent because of the difficulty of producing secondary emitters which will be stable and constant during the life of a tube.

Tetrodes

To decrease the capacity coupling between plate and grid in triodes, an extra grid is inserted in some tubes between the plate and the control grid, thus converting them to tetrodes. This screen grid, as it is called, is operated at above cathode potential but somewhat below normal anode potential. It intercepts only a very small fraction of electrons from the cathode to the plate. As long as the screen grid is negative with respect to the plate, secondary electrons are unable to escape from the plate. However, whenever the plate potential falls below that of the screen grid as a result of the voltage drop in the plate load, the screen grid collects the secondaries emitted from the plate. This results in a bend in the plate-voltage plate-current characteristic similar to that of the dynatron. This is an undesirable characteristic because it introduces distortion.

In the range where the plate is more positive than the screen, the latter emits secondary electrons which are collected by the plate. This effect is usually negligibly small, however, because the primary current intercepted by the grid is very small.

⁽¹⁶⁾R. W. Engstrom, *J.O. Soc.* 37, 420, 1947.

⁽¹⁷⁾A. W. Hull, *Proc. Inst. Rad. Eng.* 6, 5, 1918.

Pentodes

To prevent the passage of secondaries from the plate to the screen grid, an additional grid is inserted, making the tube a pentode. This grid is placed between the anode and the screen grid and is operated at cathode potential. It is called a suppressor grid because it suppresses secondary emission; that is, it prevents secondaries emitted by the plate from reaching the screen, thus avoiding the distortion that would otherwise be produced by this effect.

Beam Tubes

Another method of preventing secondaries from the plate from reaching the grid is to form a negative space charge in front of the plate. This produces a potential minimum in the space between screen and plate which serves the same purpose as the suppressor grid; that is, it prevents the low-voltage secondaries emitted by the plate from reaching the screen. This potential minimum is achieved by concentrating the primary electrons into a beam and making the plate-screen distance relatively large.

Grid Emission

Secondary emission can also take place from the grids of power oscillators when the grids operate at high-positive potentials. Attempts have been made to prevent this by coating the grids with poorly emitting materials such as C or Cr_2O_3 .

The presence of oxide-coated cathodes tends to make this procedure ineffective since alkali earth metal evaporated or sputtered from the cathode in time covers this coating. The thin layer of alkali earth metal is usually a very good secondary emitter.

In general, secondary emission from grids is not a matter of great concern because of the low potential at which grids operate. Whenever a grid is at a high enough potential so that the primary electrons which reach it result in appreciable secondary emission the grid-current characteristic may be affected. Thus, at high grid potentials the grid current may decrease because of the increasing secondary yield with increasing voltage. It may fall to zero and reverse in direction if the yield is equal to or greater than 1.

The fact that the net current to an electrode is zero does not necessarily mean that there is no heating of this electrode by electron bombardment. It has been shown that an insulated electrode when in the equilibrium state emits one secondary for each incident primary and floats at practically anode potential. Thus, such an electrode can be bombarded by a stream of high-velocity electrons, even though the current to it is zero. The energy carried away by the secondaries is at most only a few per cent of the primary energy. For instance, assuming a secondary-to-primary ratio of 10 for 500-volt primaries and an average secondary energy of 3 volts, then the fraction of the total energy carried away by the secondaries is $\frac{3 \times 10}{1 \times 500} = 0.06$. In most instances the efficiency of the process is far less than

this. The remainder of the energy of the primaries goes into heat.

Secondary Emission from Tube Walls

Secondary emission from glass surfaces can lead to puncturing of bulb walls in high-voltage tubes. A beam of electrons from the cathode may strike a spot on the bulb wall which then may reach anode voltage in the manner described in Part I in the treatment of secondary emission from insulators. For an x-ray or other high-voltage tube, the energy may be enough to overheat and soften the glass, consequently puncturing it.

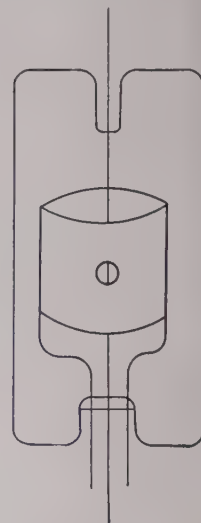


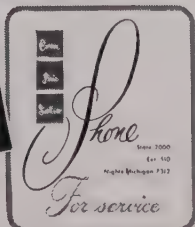
Fig. 15. Type of structure affected by charge on bulb wall

Secondary emission can produce a number of other disturbing effects in tubes. One such effect is produced when electrons from the cathode are able to reach an insulated electrode in the tube. For example, assume an anode-cathode structure with open ends or openings in the anode as shown in Fig. 15 and a conducting coating on the glass normally insulated from the electrodes. If the cathode is heated before the anode voltage is applied, in starting the tube, some stray thermionic electrons will reach this coating and charge it to cathode potential. Even after the anode voltage is applied, the coating will remain at cathode potential. On the other hand, if the anode voltage is applied to this tube before the cathode is heated, then, as soon as the cathode is heated, the electrons emitted are accelerated to high velocities by the anode. Any stray electrons which hit the coating may result in secondary yields greater than one, allowing the coating to float at anode potential. Thus, this coating may be at either anode or cathode potential, depending on the sequence observed in starting the tube. The performance of the tube depends on whether this shielding coating is positive or negative. Many such effects are observed in tubes containing insulated electrodes or insulating surfaces. These effects are often very difficult to interpret. At times the effect may be primarily due to the charge; at other times it may be due to the gas liberated by bombardment of the surface when it is positively charged.

(Concluded)

"Step up" LOCAL SERVICE with MEYERCORD DECAL

Dealer NAME PLATES



Millions of Meyer Cord dealer Decal nameplates already in use have proved their value. Used by famous department stores, like Carson Pirie Scott & Co.; retailers of home appliances, like Firestone; and leading makers of farm equipment.

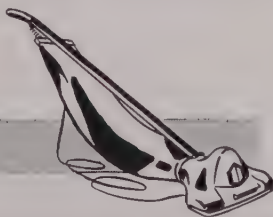
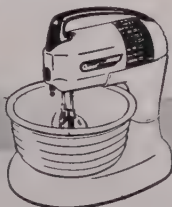
Manufacturers! Distributors! When buyers of your products need quick service—where do they find it! Has your customer an "orphan-complex?"

The old problem of the legitimate, authorized dealer versus the hole-in-the-wall, "wildcat" tinker and repairman has at last been solved by the use of Meyer Cord dealer nameplates. At no cost to the manufacturer, these colorful dealer Decals "service-mark" leading makes of home appliances, farm equipment and durable consumer goods.

Designs, colors, size and artwork are standardized by the manufacturer. Dealers pay the cost—but only 20 per cent of the price of their former individual, job-lot orders. Dealers apply the Decals! No added production problem for the manufacturer! Meyer Cord will even drop-ship these Decals after processing the dealer's name, address and telephone number on the nameplate, direct to the manufacturers' dealer.

Manufacturers pool dealer's orders, saving production costs, by direct mail solicitation or inclusion of information and order blanks in company catalogs on Dealer-Helps. Dealers appreciate the service.

Benefits multiply. The manufacturer's good name for reliability and service is maintained. Customers are pleased. Non-factory parts and irregular repairs are eliminated. Dealer's profit with follow-up business!



Find out today what Meyer Cord Decal dealer nameplates can do for you! Please address inquiries to Department 93-6.

FACTORY TRADEMARKS—IN FULL COLOR

Manufacturers! Use standard Meyer Cord Decals for nameplates, operating instructions, patent data, etc., on your products. They're colorful, durable and easily applied, at production line speeds, on any commercial surface . . . including rubber and crinkle finish. They assure lasting identification on flat or curved areas . . . despite vibration, acids, wear. No sharp edges! They can be economically produced in any colors, size, or designs.

Founder Member Lithographic Technical Foundation

The MEYERCORD Co.
World's Largest Decal Manufacturer
5323 W. LAKE ST. CHICAGO 44, ILL.

ADVERTISE • IDENTIFY • DECORATE • WITH MEYERCORD DECALS

HIGH LIGHTS AND SIDE LIGHTS

Midget Turbines

Small steam turbines, which are "midgets" when compared to the turbine-generators used to supply the nation's electric power, have been developed with engineering features previously found only in larger, custom-built turbines.

Designed on the basis of an extensive survey of the features most needed in small turbines, the new turbines can provide power for pumps, compressors, fans, and similar equipment, and can be connected to generators to supply auxiliary electric power. They may also be used in oil fields and refineries, and in locations where the fire hazard is great.

A unique governing system has been incorporated as standard equipment. It is operated by oil pressure and is completely enclosed.

Standard sets are designed to operate at 4000-5000 rpm, and only minor design changes are necessary to raise the speed up to 10,000 rpm, which is about three times the operating speed of much larger turbine-generators.

Considered by engineers an outstanding engineering achievement, the new turbines were exhibited at the International Petroleum Exposition held in Tulsa (Okla.).

Electronic Leak Detector

A recent laboratory development is an electronic instrument which looks like a pistol, but, rather than puncture a target, detects possible leaks in it.

Instead of firing projectiles, the new "gun," when directed at its target, sucks in a stream of air. Sensitive to certain types of gas and vapor such as Freon, the



Engineers inspect a model of the new small turbine which was exhibited at the International Petroleum Exposition

instrument is used for locating extremely small leaks in pressure systems. It will detect Freon leakage, for example, at as low a rate as 0.01 ounce a year.

The device will detect only compounds of chlorine, bromine, fluorine, and iodine, members of the halogen family. It responds to such vapors as carbon tetrachloride, chloroform, methyl chloride, methyl bromide, and hydrochloric acid; these vapors, compounds containing the halogens, have been detected experimentally in amounts as small as 10 parts per 1,000,000 parts of air. The instrument also is sensitive to cigarette smoke.

Compact and portable, the detector unit weighs only two and one half pounds, and its control unit fifteen pounds. It is comparatively simple to operate; the

presence of a vapor can be made to give an indication on the face of a meter, to operate a relay, or to vary the pitch in the tone of a loudspeaker.

In the conventional electronic tube, negatively charged electrons stream from the heated cathode to the positively charged anode. The new instrument operates on the contrary principle that when a suitable metal surface is operated in air at a red heat, it emits positive ions, which are atoms from which one or more electrons have been removed. These pass through the air from a hot anode to a cold cathode. When certain elements or compounds, notably the halogens, strike the hot anode, there is an increase of current as a result of an increased positive-ion emission.

The primary application for the electronic instrument is as a detector of extremely small leaks in tanks, boilers, piping, and other closed systems into which halogen compounds can be introduced as a tracer. However, because the device is based on a newly applied principle, new and now unsuspected applications are believed likely to develop.

Robot Traffic Officer

A newly developed control eliminates the annoyance occasioned by traffic lights whose operating cycles bear no relation to the existing traffic situation.

The master traffic controller can be set a week in advance to meet special traffic conditions at any given hour on any given days throughout the week. It will be possible, by means of simple dial settings on a centrally located "robot cop," to set up a traffic-control program for a whole signal system for seven days. Thus the

Mrs. Blandings' Dream Kitchen

Three stills of scenery and stars—Cary Grant and Myrna Loy—of the motion picture "Mr. Blandings Builds His Dream House," for which an electrically equipped kitchen was set up to suit even the fondest dreams of Mrs. Blandings. Replicas of the house and the complete kitchen will be shown in 100 cities in the United States



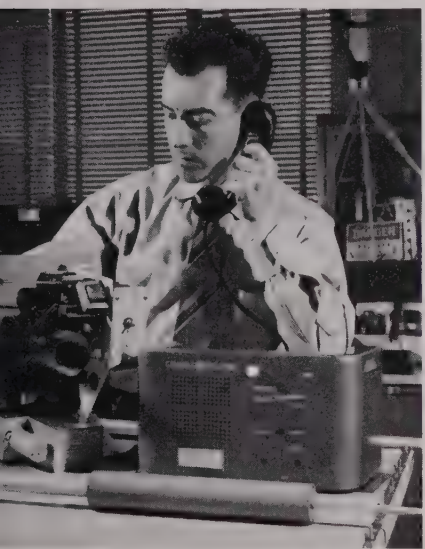
special problems of a midweek holiday's night traffic, or the jam of a noon-hour parade or five-o'clock rush hour, could be anticipated at the first of the week and taken care of by the "cop's" clockwork at the proper time.

The stop-and-go signal systems in many cities must be adjusted at individual signals or turned off entirely to meet special situations. Five of the new devices will be put into use in San Francisco to control the traffic signal systems along two thoroughfares in that city.

Marine Radiotelephone

A new marine radiotelephone, for ship to ship, ship to shore, or communication with the U.S. Coast Guard, has been developed.

Offering four-channel operation, the new transceiver operates in the FCC marine 2-to-3-megacycle radio band. It is



An adjustment is made on a marine radiotelephone unit during assembly in the laboratory

completely housed in one cabinet, with a telephone-type handset attached.

The loudspeaker operation of the receiver can be switched to handset reception for private conversations. A white light shines when the receiver is on and a red light indicates operation of the transmitter. The red lamp flickers with voice, indicating modulation of the transmitted signal. Any commercial marine type of antenna can be used.

The receiver delivers 2.5 watts of electric power to its loudspeaker. Four easily adjustable channels are selected easily by the rotary switch on the front panel. Operation is from a six-volt battery and the current is 7.5 amp.

In the transmit position the current drain is 10 amp and the power output is five watts of r-f carrier. Tests have shown an approximate range of 30 miles under

average transmitting conditions. The transmitter has four crystal-controlled channels.

Steel Thickness Continuously Measured

An x-ray thickness gage continuously measures the thickness of steel in a hot-strip rolling mill at Pittsburgh. The gage operates on the principle of x-ray absorption, the beam being directed upward from a position below the hot strip as it comes out of the rolls, and its intensity measured by means of a fluorescent screen and photoelectric cell above the strip. By this means it is possible to measure without contact the thickness of the hot steel strip with an accuracy of plus or minus two per cent.

Heretofore, all gaging of the strip thickness has of necessity been delayed until the strip cooled to a temperature at which measurement by a hand-held micrometer was possible. In this period of time a modern high-speed mill may roll six or more tons of steel. Any error in mill setting resulting in an off-gage strip is, therefore, very costly because of the large amount of off-gage material produced before the error can be corrected. The need for equipment to gage continuously the thickness of the strip as it issues from the finishing rolls has been obvious for some time.

The new instrument employs an x-ray beam passing through the hot strip and falling on a radiation detector which compares the intensity with a standard reference and shows the deviation on an indicator panel. The most difficult problem encountered in the development of the instrument was to stabilize the x-ray beam. This is accomplished by providing a second x-ray beam from the same source, so directed that it falls on a second detector, the output of which controls an electronic voltage regulator in the primary circuit.

Although the new gage is designed to fill a specific need—that of measuring the thickness of hot-rolled steel strip—the method employed is adaptable to many other gaging problems in which a non-contacting gage is desired. One such application is the gaging of cold-rolled steel strip where, because of the speed of the strip, the accuracy of contacting methods of gaging is reduced. The method can also be used with other metals and with various nonmetals.

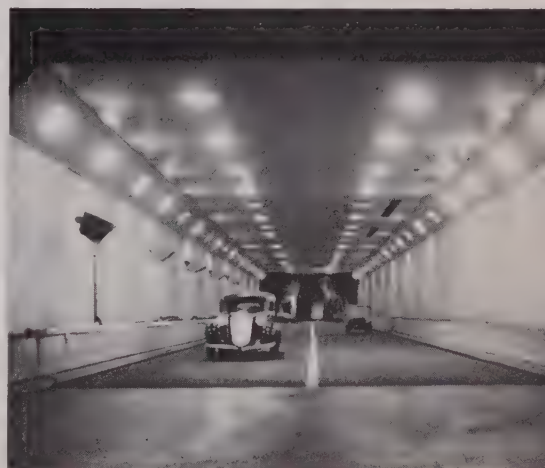
Sintered Alnico 5

A method has been perfected for sintering Alnico 5, a permanent magnet material which permits the design of intricate shapes with higher external energy than has been heretofore possible. The material is especially adaptable where small powerful magnets having high magnetic properties are required, and is expected

Tiny City Tests Metropolitan Lighting



A laboratory technician eleven stories tall smooths "pavement" of the vest-pocket shopping district of Lilliput. The thimble theater used by lighting specialists demonstrates the effects of various types of street lights on driver and pedestrian visibility and on the illumination of adjacent buildings



At the far end of the tunnel the dimly lighted heads and shoulders of a pair of technicians can be seen blocking the thoroughfare. This scale model was built for the study of the highly specialized problems of tunnel lighting without "dazzle" in installations throughout the country

to find extensive use in electronic, electrical, instrument, and novelty industries.

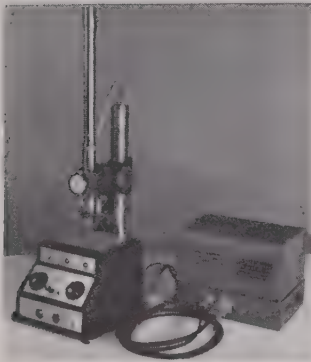
The sintering process permits the economical production of small-sized parts which are finer grained, less brittle. The material has unusually high tensile properties and can be produced with smooth surfaces and close dimensional tolerances; its fine structure also is said to eliminate crystal pick-outs and pitting.

Sintered Alnico 5 has a residual induction of 10,000 gauss and a coercive force of 575 oersteds. Its guaranteed available minimum energy is 3,500,000 gauss-oersteds for most sizes and shapes. These properties apply only in the direction of heat treatment.

The new sintered material is now being used in relays, meters, fountain pens, electronic reproducers, and compasses.

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Drill



A precision instrument called the Micro-drill for rapidly drilling accurate small holes. By means of a thermal motor feed and automatic electronic control circuits, the surface of the work to be drilled can be quickly and precisely located and the depth of the hole held to close tolerance. Both the danger of breaking even the smallest drill and need of visual observation of the drilling operation have been virtually eliminated.

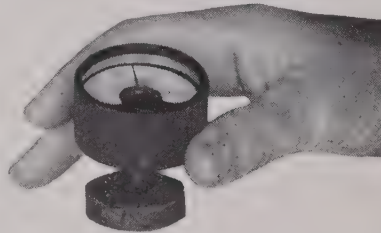
Vertical movement of the drill is accomplished by electronically controlling the amount of electric power fed into a spring-loaded thermal unit. As the power is increased, the temperature of the unit rises and it elongates, allowing a powerful spring

to lower the spindle. The action can be precisely controlled. Pilot lamps are provided to indicate "at surface" and "at depth" positions; a dial gage measures the vertical displacement.

The standard model has a collet for 0.004 in. to 0.025 in. pivot drills, and a maximum recommended electronic feed travel of 0.150 in. A variable electric drive provides a maximum spindle speed of approximately 50,000 rpm.—*Teletronics Laboratory, Westbury, N. Y.*

Gauss Meter and Kit

A new thin-probe gauss meter and a triple kit conveniently combining three gauss meters of different ratings in one carrying case. The new meter, with a probe diameter of 0.052 in., permits measurement of flux in many small-gap magnets of



standard or irregular shape heretofore excluded from the range of this type of measuring device.

The new gauss meter is a direct-reading instrument in a two-inch round Textolite case, with a hollow bronze exploring probe protruding from the back of the case. The scale, of the concentric type, covers 260 deg and is graduated directly in gausses with a substantially uniform distribution.—*Meter and Instrument Divisions, General Electric Co., West Lynn, Mass.*

Reproduction Unit

A new streamlined dry-process reproduction unit complete with Ammo-Fume dry developer designed to save time and cost of reproduction needs in drafting room, shop, laboratory, and office. By exposure and dry development, anything

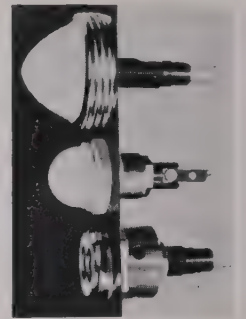


drawn, typed, printed, or photographed on translucent paper can be exactly reproduced directly from the original with black, red, blue, yellow, or sepia lines and images.

This unit permits economical intermittent or continuous-duty operation. It

develops continuous prints up to 42 in. wide from cut sheets or roll stock, in any lengths, at a speed of 5 ft per min. It also exposes blueprints and direct-process black-and-white prints.—*Peck and Harvey, 5736 No. Western Ave., Chicago 45, Ill.*

Indicating Lamps



New units have been added to a line of low-current indicating lamps to meet a demand for larger-size units for use with the Y2 slide-base bulbs as made by General Electric Co. The T2 bulb is noted for its low-current characteristics, namely 0.038 amp on 6, 12, and 24 volts, etc. When operated well under voltage ratings, long lamp life can be expected. These units are well suited for use with a series-resistor on 120, 220, 440 and 550 volts.

Unit No. 18T2 has a two-inch diameter beehive glass lens; Unit No. 59T2DE has a glass lens turned into a machined metal cap that is 1 3/8 in. in diameter. Unit No. 6T2 has a 1 1/8-in. diameter flat lens for letters, numbers, or message. All three units are for single-hole panel mounting.—*H. R. Kirklund Co., Morristown, New Jersey.*

Receptacle



The new three-outlet Sierra Triplex receptacles now being produced can easily be installed in standard boxes. These receptacles with matching wall plates are rated 15 amp 125 volts, and 10 amp 250 volts, and they are approved by Underwriters' Laboratories. They have double contacts of heavy-duty bronze, are side-wired, and a special flange and plaster ears assure flush definite alignment. The receptacle and matching wall plate are designed as a harmonizing unit, and they can be installed either vertically or horizontally. The receptacles and plates are produced in both brown and ivory, and they will accommodate two round and one flat, or three flat plugs.—*McDonald Manufacturing Co., 544 East 31st St., Los Angeles, Calif.*

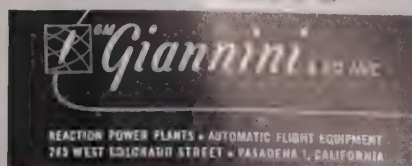
ACCELEROMETER TRANSDUCERS

Unique linear Acceleration Transducers... Measure the acceleration of launching and additional thrust and the deceleration of aerodynamic drag. These instruments provide large electrical potentiometer-type outputs proportional to acceleration. Magnetically damped with ranges from ± 5 G's to ± 100 G's. The type 2414 provides expansion of potentiometer output for special ranges. Standard resistance for these instruments is 5,000 ohms.



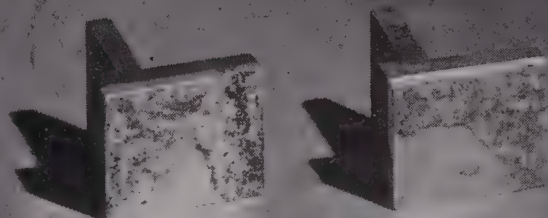
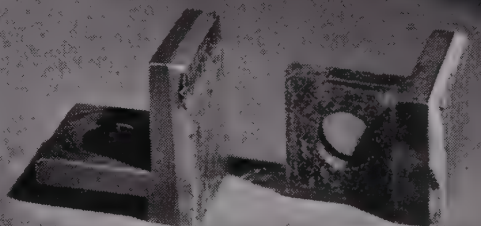
Write for complete information

Form 2412



They're made of Mallory D-54*

FACE VIEW



SIDE VIEW

*...that's why they operated over
150,000 times with practically no wear*

If you have an application that requires non-sticking, low contact resistance at high currents, we suggest Mallory D-54 as a well-proved metal for the job.

Mallory D-54 metal is a contact material of silver and cadmium oxide. Its electrical conductivity is very high and, at the same time, it has non-sticking properties. Operated continuously over long periods, it maintains a low contact resistance and shows practically no material loss. Its price compares favorably with that of silver itself.

Because of these reasons, D-54 is widely used in industrial electric truck contactors, motor starting contactors

and industrial relays and switches.

The contacts you see above are faced with a $\frac{1}{8}$ " thickness of D-54 and were used in an industrial electric truck. After more than 150,000 makes and breaks, they are practically as good as new. This performance is quite typical of D-54. We'll be glad to tell you more about D-54—glad to contribute engineering assistance also.

IT'S 5000 TO 1 THAT A MALLORY STANDARD CONTACT
WILL MEET YOUR "SPECIAL" REQUIREMENTS

*Reg. U. S. Pat. Off.

P. R. MALLORY & CO. Inc.
MALLORY ELECTRICAL
CONTACTS & CONTACT ASSEMBLIES

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA



(Above)

Complete ordering information on the Mallory line of Contacts and Contact Materials will be found in this catalog.

(Below)

The Mallory Contact Data Book contains everything you want to know about contact design, construction, application and materials. Free to engineers who write on company letterhead. \$2.50 to others.

This significant new book points the road to future research

PREPARATION AND CHARACTERISTICS OF SOLID LUMINESCENT MATERIALS

Published by arrangement with the American Physical Society, under the auspices of the National Research Council. Edited by GORTON R. FONDA, General Electric Company, and FREDERICK SEITZ, Carnegie Institute of Technology.

This volume is the outgrowth of a conference of leading scientists and engineers. They reviewed work of the past and present, and considered possible approaches to new research. The book consists of twenty-nine papers presented, and an account of the discussions which followed.

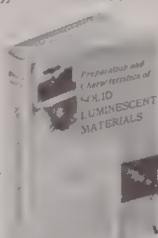
Phenomena and Theory of Storage

The book summarizes the information necessary to an understanding of luminescence phenomena, serves as a guide in preparing phosphors, and demonstrates the dependence of luminous characteristics upon measurable features of chemical composition. It explains theories now being used to determine more exactly the processes involved in the storage of luminescence energy, and describes excitation and emission phenomena.

Factors Affecting Fluorescence Characteristics

The book also deals with factors which affect fluorescence characteristics. Measurement, proper organization of experiments, and induction and decay of stored energy are discussed.

1948
459 pages
\$5.00



ON APPROVAL COUPON

JOHN WILEY & SONS, INC.
440 Fourth Ave., New York 16, N. Y.

Please send me, on 10 days' approval, a copy of PREPARATION AND CHARACTERISTICS OF LUMINESCENT MATERIALS. If I decide to keep the book, I will remit \$5.00 plus postage; otherwise I will return the book postpaid.

Name.....

Address.....

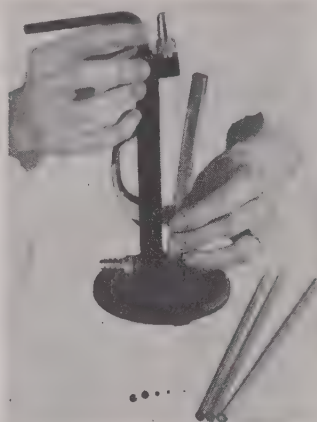
City.....

Employed by.....

(Offer not valid outside U.S.A.)

Laboratory Kit

A new rotameter-type laboratory kit designed to fill the need for a versatile and inexpensive flow-measurement set to meet the varied flow-measurement requirements of research laboratories. It consists of a



metering tube holder with base plate and hose connectors, four readily interchangeable tubes, and six metering floats complete with calibration data. Capacities range from 0.065 to 2200 cc per min of water and 5.0 to 36,800 cc per min of air.—Dept. 7 R-J, Fischer & Porter Co., Hatboro, Pa.

Velometer

A new miniature direct-reading instrument gives instantaneous and precise measurement of air velocities in unrestricted areas. This palm-sized instrument, designed for scientific application in the electrical manufacturing and engineering fields, does not require the use of jet attachments.



It is calibrated to provide direct reading of air velocity in either feet per minute or miles per hour without timing, calculations, or reference to tables and charts. Movement is double-pivoted and double-jeweled for increased accuracy. The air-actuated pointer vane and sensitive controlling hair-springs are protected by a sturdy molded bakelite case.—Illinois Testing Laboratories, Inc., 420 N. LaSalle St., Chicago 10, Illinois.

Mechanical-drive Turbine

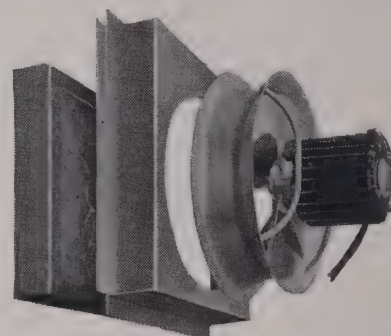
A new small mechanical-drive turbine, designated as Type DP, with ratings ranging from 10 to 1200 hp and with speeds of 1000 to 5000 rpm. The turbine is available in three single-stage frame sizes with a 16-in., 20-in., and 25-in. wheel. Embodying such features of large turbines as hydraulic governing, for wider speed range and more accurate control, and pressure oiling of

bearings to insure positive lubrication, it can be applied as a drive for pumps, compressors, fans, blowers, and similar equipment.

A new balanced valve design is used for the governing valve and the combined trip-throttle valve. With this design less force is required to operate the valves, and a given size valve can handle larger steam flows. These valves are combined in one assembly.—Turbine Divisions, General Electric Co., Schenectady 5, N. Y.

Cabinet Exhaust Fan

A propeller-type fan operating in a Venturi ring has been expressly designed for flushing instrument cabinets and transmitter cubicles. The unit, designed for both "push" and "pull" operation, is obtainable with a variety of propellers to suit different



conditions of back pressure. The fan can be mounted directly on a 10 in. by 10 in. dust filter, allowing the cabinet to be flushed with clean air and keeping it under a slight overpressure. The totally enclosed motor has two accurately aligned precision-type ball bearings with felt seals, and it can be operated with its shaft in any position. The finish on the unit is designed for operation under adverse climatic conditions.—Rotron Division, Jencks Knitting Co., Pawtucket, R. I.

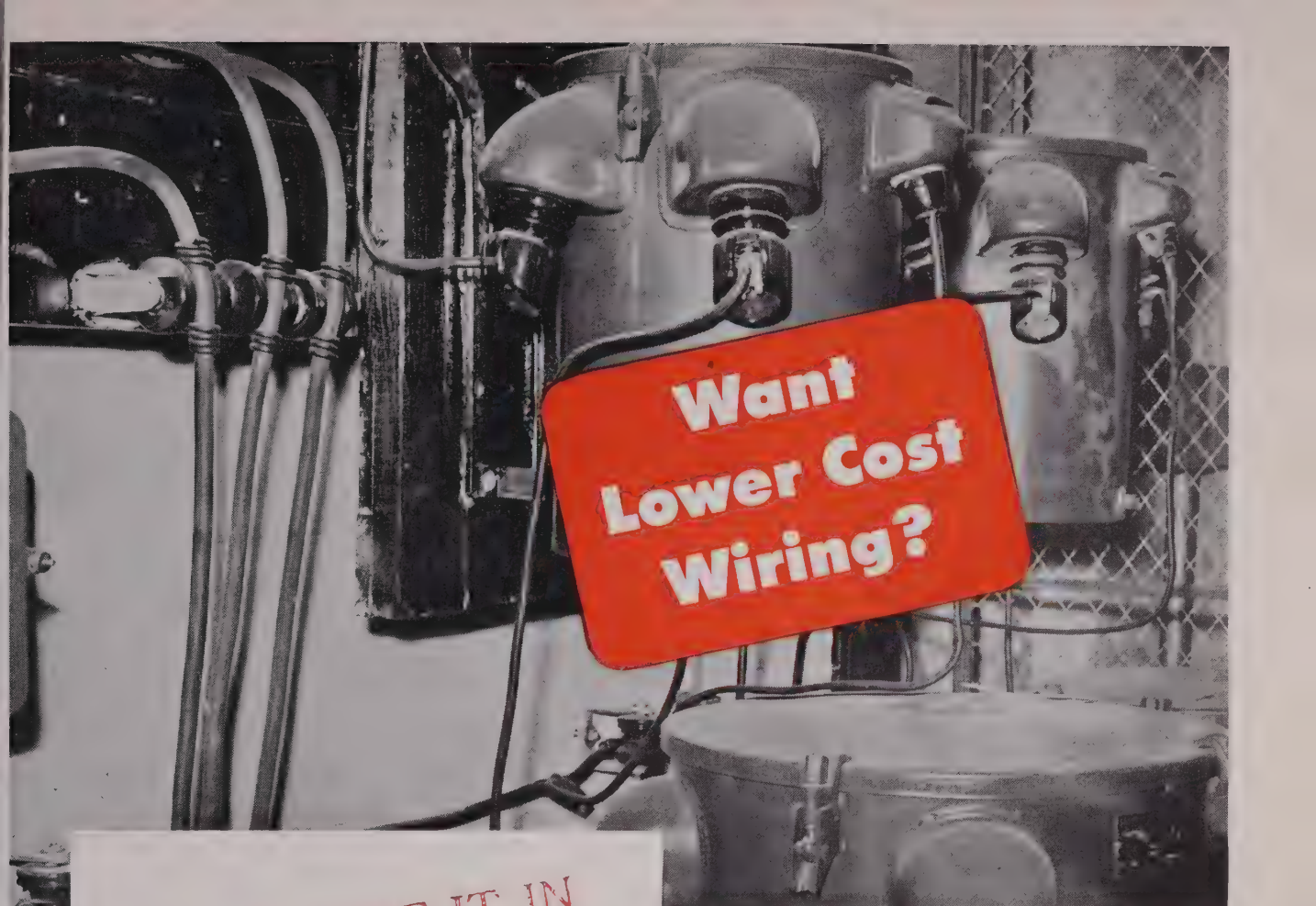
Dummy Antenna Resistors

Two new series of dummy antennas, Types D-101 and D-251, replace the former glass-enclosed Types D-100 and D-250. The new units consist of a number of special noninductively wound, vitreous-enameled



resistors connected in parallel and mounted inside a black wrinkle-finished perforated steel cage.

Residual inductance and distributed capacitance have been kept to a minimum, making the natural resonant frequency as high as possible. Also, d-c resistance, residual inductance, and distributed capacitance have been proportioned to give good response characteristics.—Ohmite Manufacturing Co., 4951 West Flournoy St., Chicago 44, Ill.



**Want
Lower Cost
Wiring?**

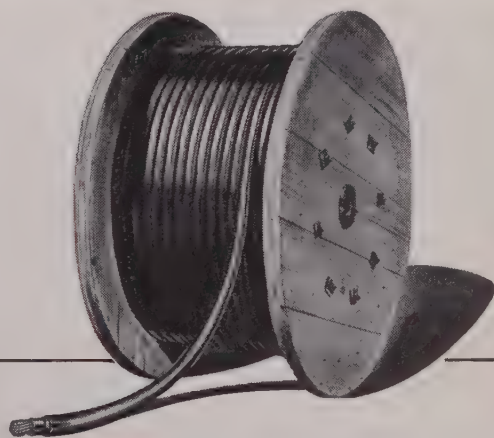
FIGURE IT IN ALUMINUM

For new plants, for rewiring for additional load—you'll save *big money* if you *figure it in aluminum*!

The lighter weight of insulated wire and cable with Alcoa E.C.* Aluminum Conductor means startling differences in wiring costs. A 500 mcm insulated aluminum cable weighs less than half the weight of an identical copper cable.

First costs are lower. Transportation costs are less. Installation is easier. Mechanical joints are easy with standard connectors for aluminum—soldering, too, with Alcoa Solder and Flux. *Welded* terminals and splices are highly efficient and easily made with aluminum.

Alcoa makes light, strong, conductive E.C. Aluminum; leading wire manufacturers draw, strand and insulate it, sell it under their own trademarks. They have it now. ALUMINUM COMPANY OF AMERICA, 2113 Gulf Building, Pittsburgh 19, Pennsylvania. *E. C.: Electrical Conductor Aluminum



The **BIG**
DIFFERENCE **YOUR SUPPLIER**
is in your **HAS IT!**
COSTS!

Insulated and sold by leading wire manufacturers

ALCOA EC ALUMINUM



FOR ELECTRIC WIRE AND CABLE

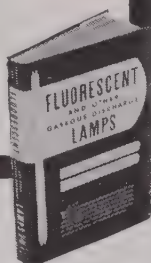


JUST OUT!

FLUORESCENT AND OTHER GASEOUS DISCHARGE LAMPS

by WILLIAM E. FORSYTHE, Physicist
and ELLIOT Q. ADAMS, Physical
Chemist (Both of the Incandescent
Lamp Dept., General Electric Co.)

304 pages, 6 x 9
152 illustrations
\$5



An engineering guide to

Fluorescent Lamps and Lighting • Photoflash
Lamps and Tubes • Infrared Telescopes • Signal
Devices • Fluorescence in Television • Sun and
Germicidal Lamps.

FUNDAMENTALS — CONSTRUCTION — PERFORMANCE — WORKING DATA

Here, in convenient form, is essential data for a complete working knowledge of fluorescent and related gaseous discharge lamp types, their physics, theory, present and potential uses, components, construction, advantages, and the engineering problems each presents. In addition to complete coverage of fluorescent lamp physics, the book includes authentic details on recent developments ranging from infrared telescopes and signalling devices to photographic flash lamps and many others. Throughout, it presents a broad array of factual and experimental data invaluable to any engineer or physicist faced with design or development problems in this fast-expanding field.



THE SNIPERSCOPE . . .
a see-in-the-dark development of the infrared telescope, one of many unique fluorescent developments described by the authors.

- CONTENTS**
1. Light and Radiation
 2. Discharge of Electricity through Gases and Vapors
 3. Basis of the Fluorescent Lamp
 4. The Fluorescent Lamp
 5. Natural and Synthetic Phosphors
 6. Fluorescent Lamp Operation
 7. Fluorescent Lamp Quality
 8. Production of Ultraviolet Radiation by Fluorescence
 9. Delayed Phosphorescence
 10. Fluorescence and Television
 11. Arc Operation and Light Output
 12. Discharges of Short Duration.



**10 DAYS FREE
EXAMINATION**

Murry Hill Books, Inc.,
Dept. GE-68,
232 Madison Ave., New York 16, N. Y.

Send me Forsythe and Adams FLUORESCENT AND OTHER GASEOUS DISCHARGE LAMPS for 10 days' examination on approval. In 10 days I will send \$5 plus few cents postage or return book postpaid. (Postage paid on orders accompanied by remittance; same return privilege.) (Books sent for free examination in U.S. only) Price outside U.S.A. \$5.50 postpaid; cash with order.

Name . . .

Address . . .

City & Zone . . . State . . .

Company . . .

Position . . .

TRADE LITERATURE

Micro Projector—This instrument, measuring or comparing objects by means of a magnified shadow image, is described in two models: (1) a standard inspection and measuring instrument; (2) a recently developed model for continuous quantity inspection of mass-produced parts. Several illustrations show the instrument in use and picture some of the accessories. Six pages. Entitled "The Wilder Micro Projector."—George Scherr Co., 200 Lafayette St., New York 12, N. Y.

Flow Meter—An instrument for measuring small flow of gases or liquids in purge systems is described. Its advantages are listed, and specifications are given in section drawings. Two pages. Bulletin No. 3—3-48.—Brooks Rotameter Company, Lansdale, Pa.

Photograph Paper—Twin booklets describe projection paper and contact paper; the first for enlarging, reducing, or restoring line drawing, printing, or writing; the second for contact photocopying. Sample sheets are enclosed in each folder. Both are eight pages. The folder on projection papers is F3-13; on contact paper, F3-8.—Eastman Kodak Co., Rochester 4, N. Y.

Power Relays—The mercury-to-mercury break of the relay is described, and the construction of the relay and its advantages are illustrated. One section shows the relay in a modified form for use with contact-equipped instruments. Four pages. Form 410.—Mack Electric Devices, Inc., 34 Glen-side Ave., Wyncote, Pa.

Galvanic Corrosion—For the production engineer as well as the research engineer, this booklet covers some of the factors influencing galvanic corrosion and presents data on how these effects can be minimized. A brief history of early investigations is also presented. Ten pages. Entitled "Aspects of Galvanic Corrosion."—International Nickel Company, New York, N. Y.

Lumber Mill Control—Log carriage drive with amplidyne control is described in this bulletin. Photographs show installation arrangements, with the control as a part of a four-unit motor-generator set. Advantages are listed, and operational features are described. Four pages. Bulletin GEA-4912.—Apparatus Dept., General Electric Company, Schenectady 5, N. Y.

Electrical Connectors—This new edition of a condensed catalog covers 13 types of multicontact connectors for radio, aircraft, communications, etc. Space is also given to solenoids, signal equipment, conduit fittings, special lights, and cable terminals. Thirty-two pages. Catalog No. C-47.—Cannon Electric Development Co., Humboldt St. and Ave. 33, Los Angeles 81, Calif.

Weld Testing—Inspection, by supersonic vibrations, of welds in plate, thin sheets, and other sections having uniform shape or contour is described in this data folder. Photographs and line drawings amplify text explanations of procedure. Six pages. Sales Data Sheet 3021.—Sperry Products Inc., 1505 Willow Ave., Hoboken, N. J.

BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

Chemical Architecture

Edited by R. E. Burk and Oliver Grummitt (*Frontiers in Chemistry*, vol. 5; published under the auspices of Western Reserve University)—Interscience Publishers, Inc., New York. 1948. 214 pp. \$4.50.

Western Reserve University's *Frontiers in Chemistry* Lectures are designed to present to graduate students and industrial chemists recent results in related fields of research. The six chapters in this volume are lectures on the structure of molecules and the relation between their structure and chemistry.

"Applications of Molecular Geometry in the Field of Reaction Mechanism" are presented by Professor H. S. Taylor for homogeneous gas and liquid systems and for heterogeneous reactions. Professor C. P. Smyth, in the chapter "Dipole Moment, Resonance, and Molecular Structure," reviews briefly the experimental determination of dipole moments and their use to determine the geometrical structure of molecules. He presents in more detail the use of dipole moments in the investigation of resonance in unsaturated organic compounds. "Structure of Co-ordination Compounds," by Professor W. C. Feineli, is a good condensed review with emphasis on methods for the deduction of structure. Professor B. E. Warren, in the chapter entitled "X-Ray Studies of Randomness in Various Materials," presents too briefly introductory material on x-ray methods, but the specific cases of randomness in struc-

tures, carbon black, and order disorder in the alloy Cu_3Au are adequate.

The most valuable chapter with regard to timeliness and completeness is that by Professor H. Mark on "Light Scattering in Polymer Solutions." This method of obtaining data about the weight average molecular weight, the average shape, and the molecular weight distribution curve of dissolved macromolecules has been developed since 1943. The theoretical background, experimental techniques, and results are given. Dr. M. W. Tamele reviews our present knowledge of "The Nature of Inorganic Gels"; the chapter serves to emphasize that "the knowledge of the nature of inorganic gels is, at present, rather inadequate and incomplete."

ARTHUR E. NEWKIRK

Preparing for Federal Radio Operator Examinations

Arnold Shostak—Prentice-Hall, Inc., New York. 1948. 414 pp. \$3.75.

The tremendous expansion of commercial radio facilities in the United States since the end of the recent war makes this book a welcome addition to the texts available to those studying for Federal Radio Operators' licenses. Questions typical of those in each of the six elements which make up the FCC examinations are included, with authoritative answers. The would-be operator will find this an excellent study guide for the particular elements he must be familiar

with in order to pass the examination for whatever class of license he desires. If he knows the answers to the questions given here, the applicant cannot fail the test.

The author, who is a member of the Institute of Radio Engineers, is well qualified to assemble a book of this type, as he was formerly a radio inspector for the FCC. He has given and graded thousands of examinations for radio operators' licenses.

Not only will the book be of value to those preparing for examinations, but its complete subject index and its concise treatment of fundamental technical and legal aspects of radio communication make it an invaluable handbook for radio operators, technicians, and experimenters.

R. E. ANDERSON

Electric Power and Government Policy: A Survey of the Relations between the Government and the Electric Power Industry Factual Findings by the Research Staff; Program by the Power Committee—The Twentieth Century Fund, Inc., New York. 1948. 880 pp. \$5.00.

In 1938 the Twentieth Century Fund trustees appointed a distinguished committee, under the chairmanship of J. Henry Scattergood, to survey the relations between government and the electric power industry, and to draft a national power policy in the best interests of the people as a whole. The committee summarized their findings in an article, "The Power Industry and the Public Interest," by Edward Eyre Hunt, published in February 1944. Now their complete report has been printed in an 860-page volume, packed with facts and figures, that reviews the progress of industry and its relations with government over the past 40 years.

Electric power is now hardly less essential than the bread we eat and the water we drink. Subways, elevators, lighting, water supply, factories, radios, newspapers, and many of our domestic furnaces and stoves would stop if electric power failed. This service is founded on an investment amounting to over ten per cent of all the assets of American industry, but on the daily efforts of only one half of one per cent of all American wage earners. The labor required to make electric power must be invested beforehand in building dams, generators, power houses, transmission lines, and the service lines to homes and industry.

The attraction and fair treatment of investors is a central problem of the industry that is fully as difficult and controversial as the labor problems that other industries must contend with. The problem is especially difficult because the power industry is required to pay higher taxes as a fraction of income than any other business except the liquor, tobacco, gasoline, and possibly the communication groups. Also, there is competition from government-operated power plants, which pay no such taxes.

With this importance, and such dependence on investment, it is no wonder that electric power has been a storm center of political controversy for a generation. Despite bitter arguments of extremists on both sides, however, steady progress has been made, and problems have been solved as they arose by the good American process of debating, compromising, experimenting, revising, and again experimenting.

This volume tells the fascinating story of that progress, recording the trials made, decisions reached, and success attained in each state and by each branch of the power industry over 40 years. The story is illustrated by 39 charts and 116 tables, comparing output, rates, costs, earnings, taxes, and assets from every angle. Although the

statistical data stop at 1940 and are, therefore, far out of date, the records of debates, of legal practices, and of solid achievements give the book an outstanding and permanent value. It deserves to be read and pondered over by all those who are concerned with the further growth of the power industry.

Especially important are the concluding words of the committee:

"The final question is one which no committee can answer. That is the question as to the attitude which the public, of which government is only the organized representative, will take toward this great and vitally important business organization.

"In part, that depends largely upon the industry itself, upon its willingness to discipline itself, to avoid the repetition of the evils of the comparatively recent past, and the pitfalls which tremendous power resulting from the control of vast aggregations of capital places before the feet of the best-intentioned men. In part, it depends upon the devising of a system of regulation which will control without unduly hampering initiative, and will reward imagination and efficiency. And finally, it will depend upon the realization of the public that neither here nor elsewhere can it get something for nothing. It cannot get taxes which cripple the industry. It cannot get service without paying reasonably for it. It has a right to fair treatment and to the lowest rates which efficiently managed virtual monopoly can possibly give it. But it has no right to more."

P. L. ALGER

Best's Safety Directory—1948 Edition

Safety Engineering Magazine, Division of Alfred M. Best Co., Inc., New York, 1947. 494 pp. \$5.00.

Best's Safety Directory contains catalogued information on a large number of safety devices and appliances, fire-protective and fire-fighting equipment, machine guards, and many other materials that concern industrial safety directors, medical directors, plant engineers, and plant managers. The present edition contains numerous illustrations and descriptions of safety devices, explanations of the use of each device to control a particular hazard, and the names and addresses of manufacturers of each device. The classification of devices according to their basic uses is helpful.

C. R. DeREAMER

Fractional-horsepower Motors

Cyril G. Veinott—McGraw-Hill Book Co., Inc., New York, 1948. 584 pp. \$5.00.

There has been a definite need for an up-to-date instruction book on fractional-horsepower motors. Mr. Veinott's second edition fulfills the need quite satisfactorily. All types of fractional-horsepower motors—split-phase, capacitor, repulsion, universal, polyphase, direct-current, and others—are explained in easily understandable language.

Rewinding motors for different operating characteristics, selection of capacitors, testing procedures, selecting a motor for a job, and many other service problems are clearly and completely answered. The author has also included a glossary of definitions of electrical terms and an appendix which contains valuable information in table form on trouble diagnosis. Mr. Veinott has succeeded in his attempt to present the information in such a way that it may be used as a textbook for classroom study or as a reference manual by repair men.

Fractional-horsepower maintenance men and operating engineers will find this book an invaluable tool for their work.

W. M. SCHWEDER

SMALL RUNS on small parts AT BIG SAVINGS

NEW METHOD CUTS TOOLING COSTS

Want to get precision parts in pilot lots without paying a fortune for tools? Or do you want just a few close tolerance stampings to prove your design before investing in permanent tools? The Short-Run Department of Instrument Specialties Co. is geared to handle just such headache jobs. And fast.

I-S methods eliminate costly tooling on shearing, bending, piercing. Precision is comparable to that obtained with permanent tooling. Delivery is quicker, cost far less. Parts can be produced in our Short-Run Department in any quantity, up to the point where permanent tooling becomes less expensive. Beryllium copper or any other heat treatable alloy lends itself to this new technique.

The I-S Short-Run Department is saving big money for some of America's best known concerns. An inquiry concerning your problem will get immediate attention



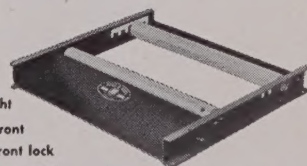
INSTRUMENT SPECIALTIES CO., INC.
Bergen Blvd. Little Falls, N. J.

TO REEL OR UNREEL THE EASIEST WAY

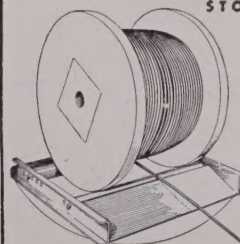
WHATEVER YOU USE ON A REEL . . .
WIRE, CABLE OR ROPE. SAVE TIME AND LABOR WITH

ROLL-A-REEL

Portable
Lightweight
Slanted front
Positive front lock
No jacks needed
Adjustable slots for many widths



TAKE IT TO REEL,
STORAGE OR JOB



Style A:
2,000 lbs. cap.
37.50

Style B:
4,000 lbs. cap.
75.00

f. o. b. Cincinnati

ASK FOR DETAILS IMMEDIATE DELIVERY

ROLL-A-REEL

327 WEST FOURTH STREET
CINCINNATI 2 OHIO

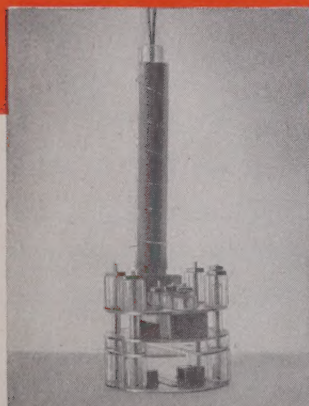
URANIUM

U-235

detector employs NICHROME*V exclusively



60" Mass Spectrometer Tube



Ionization Source



Mass Spectrometer—Model M60
(Process & Instruments,
Brooklyn, N. Y.)

THE Mass Spectrometer, which has played vital roles in the discovery of U-235 and its subsequent applications in fields of atomic energy and cancer research, is one of the most important measuring instruments of the modern age. Its ability to crack molecules and then sort them according to mass makes it unique for analytical purposes.

Materials entering into its construction must be superlatively stable, assuring the highest degree of accuracy at all times, and retain their characteristics unflinching throughout a long life of trouble-free service.

Specifications for the metal used in the Ionization Source and Collector System typify the super-critical requirements that have to be met. The metal must be:

- (a) non-magnetic (i.e. remain unmagnetized in the presence of the powerful magnet used in the Mass Spectrometer);
- (b) able to withstand temperatures of approximately 665°F. in a vacuum of 10^{-7} mm. mercury *without deformation or evaporation*;
- (c) non-porous, and non-absorbent of gases;
- (d) easily machined, drilled, tapped, threaded, and spot welded;
- (e) available in wire, sheet and rod forms.

"Of all available metals" states Process & Instruments Inc., of Brooklyn, N. Y., makers of Mass Spectrometers, "Nichrome V most satisfactorily meets all these requirements and hence, with the exception of the tungsten filament, is exclusively used by us in the construction of the Mass Spectrometer. In addition, a Nichrome heating element is used for outgassing the Spectrometer Tube of absorbed moisture".

If you have particularly exacting specifications to meet, consult with us. There are more than 80 Driver-Harris alloys specifically designed to fill the requirements of the Electrical and Electronic Industries. The fruits of our 48 years of specialized research experience are at your service.

Exclusive Manufacturers of Nichrome

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco, Seattle
Manufactured and sold in Canada by
The B. GREENING WIRE COMPANY, LTD., Hamilton, Ontario, Canada



*T.M. Reg. U. S. Pat. Off.

LIBRARY NOTES

ON ARTICLES IN OTHER TECHNICAL JOURNALS

ADHESIVES

Industrial Adhesives.

Kenneth Rose—*Mat. & Methods*, Feb., 1948; v. 27, pp. 93-104.

The basic information on adhesive types, and the general uses for which groups are intended, to help determine what general class of adhesive should be used.

AIR CONDITIONING

Survey of City Water Supply Systems.

S. C. Moncher—*Refrig. Engng.*, Feb., 1948; v. 55, pp. 162-165, 193-194, 206.

Presenting data for 56 cities on present capacities, restrictions on use, and contemplated expansion for air-conditioning needs.

CALCULATING INSTRUMENTS

An Electronic Differential Analyzer.

J. S. Koehler—*Jour. App. Physics*, Feb., 1948; v. 19, pp. 148-155.

Designed to solve ordinary nonlinear, non-homogeneous differential equations or the boundary-value problems based on such differential equations.

CORROSION

Fretting Corrosion.

Lubrication, Mar., 1948; v. 34, pp. 25-36.

Also known as false brinelling or friction oxidation; a particular type of metal corrosion or oxidation which occurs on the contact areas of loaded metal surfaces subject to oscillatory or vibrating motion.

DIE CASTING

Die-casting Magnesium.

Herbert Chase—*Iron Age*, Feb. 26, 1948; v. 161, pp. 68-72.

Operations conducted at the plant of Litemetal Dicast, Inc., in the production of a large variety of magnesium die castings.

ELECTRIC LAMPS

Repetitive Flashing of Hot Cathode Fluorescent Lamps.

Fred J. Vorlander and Sigmund Stawicki—*Illum. Engng.*, Mar., 1948; v. 43, pp. 231-249.

A method of successfully operating hot-cathode fluorescent lamps in a flashing circuit.

ELECTRIC WELDING

Resistance Welding of Light Alloys.

E. J. Keefe and L. B. Wilson—*Lt. Metals*, Mar., 1948; v. 11, pp. 139-144.

The authors describe spot- and seam-welding techniques and consider certain major difficulties hitherto associated with the application of these to aluminum.

ELECTRON ACCELERATORS

Linear Electron Accelerator.

E. L. Ginzton and others—*Rev. of Sci. Instr.*, Feb., 1948; v. 19, pp. 89-108.

Some theoretical and experimental work which has as its end object the production of electrons of energy 10^9 ev, or thereabouts, by means of a device called a linear electron accelerator.

FURNACES, INDUSTRIAL

Atmospheres and Controlled-atmosphere Furnaces for Nonferrous Metals.

William Lehrer—*Metal Prog.*, Mar., 1948; v. 53, pp. 393-402.

Information on modern practice in bright annealing of the heavy nonferrous metals

and alloys, with some notes on recent practice in the precious-metal industry.

GENERATORS

Improved D-c Generators for Reversing Mills.

C. Lynn and W. H. Burr—*Iron & St. Engr.*, Feb., 1948; v. 25, pp. 45-55, 70.

Laminated-steel generator frames, instead of the usual solid design, to give better operation of reversing-mill d-c generators during transient load changes.

HEAT PUMP

Heat Pump Water Heater Obtains Heat from Cellar Wall.

F. M. Reed—*Elec. Lt. & Pr.*, Feb., 1948; v. 26, pp. 74-75.

An experimental installation made to determine the feasibility of obtaining heat or dissipating heat within the cellar of a building for any household medium-temperature heating or cooling requirements.

MACHINE DESIGN

Designing for Economical Manufacture.

Benjamin N. Ashton—*Mach. Design*, Feb., 1948; v. 20, pp. 101-106.

Improved performance as well as simplified manufacturing are the concrete result of giving production methods adequate consideration during design.

METALS—COLD-WORKING

Cold Heading Cuts Manufacturing Costs.

Chester S. Ricker—*Am. Mach.*, Feb. 26, 1948; v. 92, pp. 89-91.

How replacing screw-machine or milling operations by cold heading can effect over 50 per cent material and labor saving.

NOMOGRAMS

Construction of Alignment Nomogram From Empirical Data.

Lo-Ho—*Franklin Inst. Jour.*, Mar., 1948; v. 245; pp. 227-244.

A general method of constructing alignment nomograms from a tabulation of values.

PHOTOGRAPHY

Cinema-spectrograph for Photographing Rapid Spectral Sequences.

Robert C. Herman and Shirleigh Silverman—*Optical Soc. of Am. Jour.*, Feb., 1948; v. 38, pp. 209-211.

Built for the purpose of obtaining spectrograms from light sources showing transient phenomena—in particular such light sources as the new types of rocket and jet combustion engines.

RAILROADS

Do First Costs Retard Electrification?

L. W. Birch—*Ry. Age*, Feb. 21, 1948; v. 124, pp. 380-383, 394.

How total cost might be reduced 11 to 14 per cent by improved methods of design and construction procedure applied to the contact system alone. Summary of an AIEE paper.

SYMBOLS

The Story of the Welding Symbols.

Leon C. Bibber—*Weld. Jour.*, Feb., 1948; v. 27, pp. 101-107.

Explains the purpose of the AWS symbols and how they may be used.

THERMOSTATS

Bellows Type Thermostat.

John R. Parks—*Tool Engr.*, Feb., 1948; v. 20, pp. 27-30.

Presents several theoretical considerations on procedures for manufacture.

TRANSFORMERS

Large Transformers Grow Smaller With Improvements in Design.

Frank Snyder—*Elec. Wld.*, Feb. 28, 1948; v. 129, pp. 74-77.

Improved insulation structure, better core steel, and tank designs that conform to the shape of modern shell-form cores make higher transformer ratings possible in units of smaller size.

VACUUM SEALS

High Vacuum Valve and Seal.

L. D. P. King—*Rev. of Sci. Instr.*, Feb., 1948; v. 19, pp. 83-84.

A simple two-way valve and a method of making a seal are described, both well adapted to large or small port openings in high-vacuum work.

VENTILATION

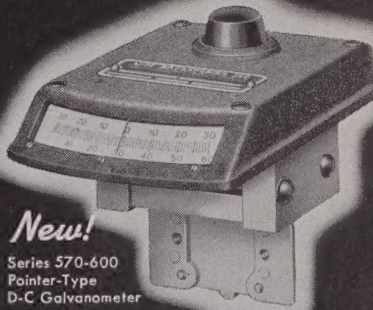
State Laws Concerning Industrial Exhaust Ventilation.

Knowlton J. Caplan and Allen D. Brandt—*Heat. Piping & Air Cond.*, Feb., 1948; v. 20, pp. 118-123.

A summary, in tabulated form, of the principle provisions in each state.

Specify... 

D'ARSONVAL PORTABLE
GALVANOMETERS
AND MOVEMENTS...



New!
Series 570-600
Pointer-Type
D-C Galvanometer

Here is a new addition to the line of G-M galvanometers. It is a completely assembled unit featuring an Alnico magnet for greater stability of calibration and a new high in sensitivity. Easily installed and replaced, requires only 2 3/4" below the mounting surface. Rugged construction throughout. Three models, with sensitivities per mm. division of .06, 0.10 and 0.20 microamps.

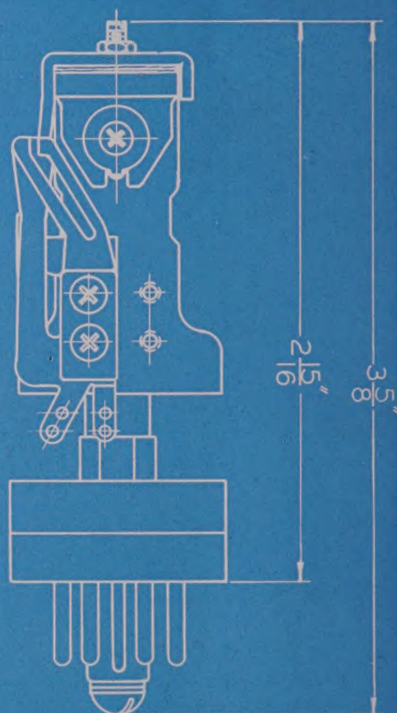
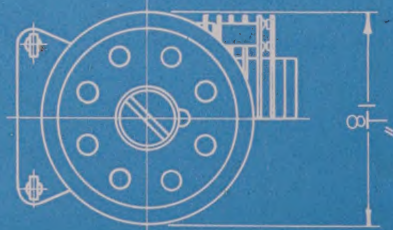
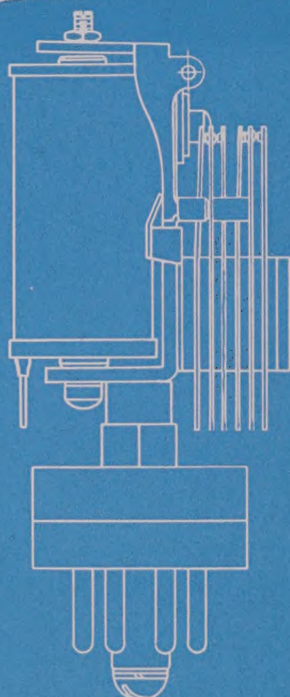
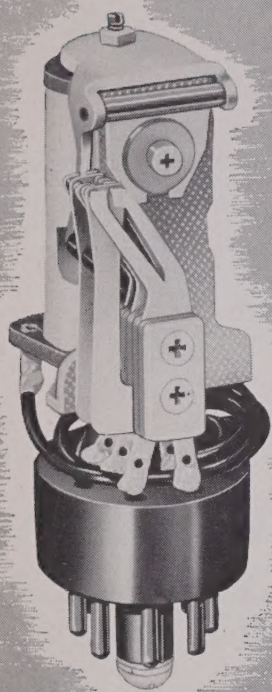
Write for specifications and prices on these and other galvanometers

 **LABORATORIES, Inc.**

4318 N. Knox Ave. • Chicago 41, Ill.

NOW... The CLARE Type "J" Relay can be Mounted as Conveniently as a Radio Tube!

Famous Clare Type "J" d-c Relay
now available in plug-in type where
quick removal or replacement is desirable



Specifications of Clare Type "J"
d-c Relay with plug-in
mounting.

Clare Type "J" d-c Relays combine the best features of the conventional telephone type relay with the small size and light weight which modern compact design requires.

Check these outstanding features of Clare Type "J" design which provide hitherto unheard of performance by a small relay:

- ★ Independent Twin Contacts
- ★ High Current-Carrying Capacity
- ★ Large Armature Bearing Area
- ★ Efficient Magnetic Structure

- ★ High Operating Speed
- ★ Large Contact Spring Pileups

Clare sales engineers, with long experience in every type of relay problem, are located in principal cities. They will be glad to provide you with complete engineering data on the Clare Type "J" Relay, show you how it may be "custom-built" to meet your exact requirements.

Look for them under "Clare Relays" in your classified phone book . . . or write C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Ltd., Toronto 13. Cable Address CLARELAY.

CLARE RELAYS

First in the Industrial Field